THE SEPTEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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REMINISCENCES

BY

GEORGE HENRY FOX, A.M., M.D.

Formerly Professor of Dermatology, College of Physicians and Surgeons, Columbia University, New York.

Excerpts:

Hebra was a most remarkable man and in his daily clinics showed a keenness of observation which was simply wonderful. He rarely asked his patient any questions, but a hasty glance would usually enable him to tell more about the case than any one of his students would elicit by a lengthy catechism. Taking the patient's hand in his and looking straight at the class he would say "this man is a tailor" and we soon found that he discovered this fact by feeling the needle pricks on the roughened forefinger. A hatter he would recognize by some peculiar callus on the ball of the thumb and whether a patient was a confirmed beer or brandy drinker he knew by the appearance of the nose and the velvety condition of the skin. He could always guess the age and weight of a patient with unerring accuracy and tell us from what province of Austria he came. He could usually tell about how long an eruption had existed and repeatedly told his pupils not to ask whether an eruption itched but simply to look carefully and note the presence or absence of scratch marks.

One day a patient came in limping, and sat down to remove some bandages from his legs. While patiently waiting, Hebra casually glanced at him and remarked, "This man is a Croat, 55 years of age, has pulmonary tuberculosis and is a tailor by occupation." As he had not had a chance to see or feel his forefinger some of the students smiled at the statement, observing which he quickly asked, "wouldn't you know he was a tailor? Look at that little strip of drab cloth he has tied around the bandage. Tailors use that stuff for vest linings."

His power of imitation and of vivid description fully equalled his keen observation. One day a deaf mute came to the clinic and Hebra took occasion to refer to what was being done in Vienna for the unfortunate class by means of lip study. He said that children learned in a few months, to speak plainly but that their voices always had a peculiar lack of accent and intonation. He then gave an imitation of their speech and as I had visited the institution the week before I was amazed to note that the imitation was absolutely perfect. Another day a stupid boy, asked as to his occupation, said that he was a tailor. "Du bist kein Schneider," roared Hebra, "you are not even an apprentice. You pick up the litter at night and sweep out the shop in the morning. You go out for the beer at midday and rock the cradle when the Frau is preparing the dinner. That is the kind of a tailor you are." In short, with a few rapidly spoken sentences he gave us a word picture of that boy's habits and doings which was doubtless as accurate as it was amusing.

Vidal was a handsome and affable man but I acquired a dislike for him through no fault of his own. One day he exhibited a patient to a small group who were walking the wards with him and suddenly called on me for a diagnosis. Surprised and flustered I glanced at the numerous and disseminated small papules and hastily expressed my first thought "eczema." It happened to be a typical miliary papular syphilide and the expression on his face seemed to me to declare in loud tones that I was a hopeless ignoramus. I felt that I had not only injured my own unmade reputation but had utterly ruined that of the Vienna school. I walked home sad and dejected. My intense chagrin over my blunder almost banished sleep that night and for days and weeks I never saw M. Vidal at a distance without feeling that he recognized me as that young and foolish chap from Vienna who didn't know the difference between eczema and syphilis. Since that time I have made many mistakes in diagnosis but all of them put together have never given me serious discomfort or disturbed my sleep.

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Vol. XLIII, No. 3 September, 1936 Whole No. 252

The Scientific Monthly

An Illustrated Magazine Devoted to the Diffusion of Science

J. McKEEN CATTELL, Editor

WARE CATTELL, Associate Editor

Published by THE SCIENCE PRESS

LANCASTER, PA.—NEW YORK, N. Y., Grand Central Terminal—GARRISON, N. Y.

Single Number, 50 cents Yearly Subscription, $5.00

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Entered as second-class matter at the post office at Lancaster, Pa., July 18, 1923, under the Act of March 3, 1879

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SEPTEMBER, 1936

THE SOCIAL ORIGINS OF DIETARY HABITS

By Dr. ROE E. REMINGTON

PROFESSOR OF NUTRITION, MEDICAL COLLEGE OF THE STATE OF SOUTH CAROLINA

In 1906 Dr. Henry H. Donaldson, of the Wistar Institute, published charts and tables showing normal growth in the albino rat, an animal which has been bred in captivity for many years and extensively used for research purposes. His rats were reared on what was supposed at that time to be a fully adequate and satisfactory diet. During the thirty years that have followed, as our knowledge of nutrition has grown by leaps and bounds, and has been reflected in the improved feeding of rat colonies in our research laboratories and scientific institutions, the rate of growth of normal rats has been trebled, and adult size increased, so that it is now common to find mature male rats weighing as much as 700 grams, a thing that was unheard of thirty years ago.

The pangs of hunger drive man to seek food. This has always been true, but it remained for Carlson to show that hunger is a concomitant of more or less powerful and spastic contractions of the stomach. To allay hunger, one eats, and derives pleasure in the eating, but the choice of articles which he uses as food depends on availability and appetite. It is appetite which leads us, when given a choice, even though limited, to eat one article and reject another.

The modern biochemist, with his vast accumulation of data as to the human requirement for protein, fat, carbohydrate, mineral and vitamin, and with tables of analyses of all common foods to guide him, finds that many peoples in many places, when guided by appetite, that is to say, by customary usage, do not select for themselves a fully balanced and adequate ration.

This newer knowledge of nutrition, for which we are indebted to the sciences of chemistry and physiology, has found rapid and ready acceptance among breeders of live stock, who have a financial interest in the result, but its influence on human dietary habits has been much less evident, so that it has seemed of interest to inquire as to the origins of the food habits of man, different races of man, in the light of the degree to which they may have been influenced by a conscious or subconscious knowledge of biology and chemistry, by geography, by economics, by religion or superstition or by the general mode of life and pursuits of different peoples. These latter factors, derived from the geographical, economic or social status of the people, I shall consider under the name of social factors, as contra-distinguished from the chemical composition and physiological value of the food itself, which I shall call biological factors.

A study and evaluation of the social factors which have influenced the diet of man is vastly more difficult, and less certain, than of those in which chemistry and physiology are involved. It leads us back to the very dawn of human life,

concerning which we must indulge in a certain amount of speculation of a kind which is more or less repugnant to the modern scientist. It leads us to consider the religions of man throughout the ages and his tribal customs in so far as they prohibit or encourage the use of this or that article of food. It leads us to consider the nature of the land in which he dwelt, whether adapted to an agricultural, a pastoral or a nomadic life and, finally, it leads us to study commerce and industry.

Even to-day, and among the most enlightened people, we find widely current the belief that our pioneer ancestors or even their semi-savage progenitors, eating the products of field and forest, grinding their grain in a crude mortar and without access to modern refined foods, enjoyed a more complete and rational nutrition than do we to-day. Civilization, they say, has led man to discard and forget the rules of a sane and rational dietary régime and has created perverted tastes and appetites which are undermining the vigor of the race. To hold with such a view we should have to postulate that primitive man possessed an instinct which led him to accept this or reject that, from among all the plants of the fields and the game of the woodlands, according to his own physiological needs. Many still believe that, despite his veneer of civilization, man to-day possesses this instinct, which expresses itself in his likes and dislikes and which has been inherited from his jungle ancestors. Such an instinct can not be demonstrated with certainty among the lower animals, which are still wild and have free choice. From my youthful days on the farm, I recall that a horse must be taught to eat oats, a calf to eat clover, and that any abrupt change in ration will cause animals to "go off their feed," even though the new ration be as complete and perfectly balanced as the old. The dog, a domesticated wolf, will not as a rule eat fish, perhaps because in his free state fish was inaccessible to him. I know a Belgian police dog that suffered at one time from black-tongue and for which canned salmon was prescribed as an anti-pellagric food. He could be induced to eat it only by starvation and never learned to take it willingly. On the other hand, I have a terrier which was raised with a family of kittens, which were taught by the mother cat to eat fish. The dog ate the fish to get it away from the cats and thus acquired a fondness for it while still young. If such an instinct exists, it is an instinct, common to man and animals, of distrust for anything the taste of which is strange or new.

Bordeaux, in his history of alimentation, published in 1884, says of primitive man that "oppressed by constant hunger he ate, according to chance, his only provider, without being able to choose; unsuitable prey and repulsive food, insipid or sour berries, suspicious fruits and larvae of insects, mollusks, batrachians, reptiles, and even at need the grass of the prairie. There were more things capable of being eaten and of furnishing some nourishment, good or bad, than we suspect to-day. Originally necessity caused all of them to be eaten." Engels says: "Primitive man, escaping from the animal kingdom, still retained traces of his ancestry. He was a semi-beast, crude, weak against the forces of nature, ignorant of his own strength, and for that reason just as helpless as the animals." Roubakine, from whom I have drawn freely in the argument which follows, says of man of that age that "in the forests of the quaternary period he gathered roots, tubers, grain, and some wild fruits; caught larvae, worms, grasshoppers; ravaged the nests of birds and ate their eggs. Not having equipment or strength to catch or kill large animals, he ate such small ones as he could waylay, or the flesh of dead animals which

he might happen to come upon. In the sea and rivers he obtained crustaceans and shell-fish."

The eating of insects did not perish with prehistoric man. The Hebrews were permitted to eat grasshoppers and locusts, and in fact employed quite a variety of insects. John the Baptist was nourished, during his stay in the wilderness, by locusts and wild honey, and it is said that the Greeks applied the epithet of "acridophages" to the people of Lybia because they ate grasshoppers. Even to-day they are served in China under the name of "shrimps of the earth." The Romans ate, as a delicacy, the larvae of several species of beetles, and the East Indians and Africans use ants as a delicacy.

So far as primitive man is concerned, his struggle for existence was so difficult that he could not exercise much choice as to his food. He had to eat what he could get or die. Eating was synonymous with life, a fact which finds expression in the idioms or origins of words in most languages. In English we speak of "one's living," as applied to food; in French "être," in German "essen," in Latin "esse," in Russian "ieste," all have the same double meaning.

Naturally there were some among the articles used as food by primitive man which caused illness or even death. With his rudimentary reasoning powers, it must have taken many years for him to learn to avoid them. Can it be that such knowledge, handed on from generation to generation, could have fixed itself in human physiology in the sense of taste? But, if so, why should taste, acquired as a protection against harmful or poisonous foods, lead one race of mankind to rely heavily on a certain article of food, another to reject it *in toto*? Take, for example, so common and, among us, so universally used an article as milk. Savage man had no domestic animals, hence did not have milk, which only appeared as an article of diet with the coming of pastoral peoples. Even so, not all keepers of live stock used milk. Homer referred to milk as food suitable for barbarians, whom he called "galactophages," and Herodotus thought it worthy of note that the Scyths employed milk as a usual food. Bordeaux says that in China and Eastern Siberia milk is not used at all, the people of these regions calling it "white blood" and having a distaste for it. In other words, the use of the milk of animals as human food did not arise through an instinctive sense of taste, but rather because the domestication of lactating animals made it available, and perhaps only then because scarcity of other food made it necessary to rob the calf to feed the baby.

In the recorded history of some uncivilized peoples, and among certain savage tribes to-day, we find that different rules of diet are laid down for different classes; some articles of food are forbidden to women and children but permitted to men, or other articles are restricted to a special group. Let us speculate for a moment as to how this may have come about. Before the invention of weapons or the advent of tribal life, the obtaining of food could be as easily accomplished by the female as the male. Monogamy and the family did not exist, and there was complete equality between man and woman, a condition which has not obtained since, even to our day. Except that babes and children were cared for by their mothers, there was no division of labor. The aged and infirm were abandoned to perish.

Perhaps through accident, man learned that he could bind the tusk or horn of an animal to a staff, and thus become superior to the beasts, in that he could kill them at a distance. As implements of the chase became improved and perfected, there arose a division of labor, first between men and women, later between men of different ages. The

weapons of the chase were heavy, and required a certain degree of strength and skill in their manipulation. The hunters thus became the select class, for whom the best in the way of food and other necessities of life should always be reserved. But the old men, wise in the ways of game and experienced in making weapons, acquired a new value to the tribe, and hence were no longer left to die, but provided for as equal or only slightly inferior to the hunters.

Since the fortunes of the chase were variable and not to be depended on at all seasons, the products of the field could not be entirely abandoned, and it was the women who devoted themselves to the harvest. They gathered seeds, herbs and fruits, learned to plant and till the soil, and so agriculture was born. Among most primitive peoples the god of the flocks and forests is a male and that of the fields a female.

This division of labor between the hunt and agriculture has been responsible for differences in social usages and tribal customs. Where there was an abundance of game and little reliance need be placed on tilling the soil, the dominance of the male was unquestioned. But where the hunt was precarious, and the main subsistence of the tribe derived from the fields, woman ruled the tribe.

This division of labor resulted in some social usages among primitive men which still exist among certain savage peoples. Among these are: men were forbidden to eat the flesh of female animals and women of male; if such a prohibition existed among enlightened peoples we should doubtless explain it by referring to the hormonal secretions of the gonads! Woman was forbidden to hunt lest she frighten the game (hunters still think so); the best parts of the game and of other food were set aside for the old men; women and children were forbidden to eat certain parts of the game. Spencer cites the observation of Edward John Ayre that numerous such rules of diet exist among some wild tribes in Australia, prompted not by a knowledge of physiology or chemistry, but by the desire of the grown men to reserve for themselves the best parts of meat and fish. In these tribes the young are not allowed to eat of the meat of the emu, of pork or of large lizards, for if they do their bodies will surely swell up and their hair turn white. A woman must not eat of the wild guinea, for if she does her cheeks will swell. Eating of the wild dog will bring on a goiter, or of the kangaroo will cause her head to swell, or the wild hare her entire body to swell. If she eat fish she will surely have ulcers on her legs. But strangely enough none of these things happen to men who consume such delicacies. The rules of magic and primitive religion are called into play to insure observation of these taboos, designed to protect the males in their right to the choicest and best of the food.

The domestication of animals must have originated early in tribal life. Occasionally, in the chase, animals could be taken alive, and were preserved, perhaps against a day of want, more likely for fattening. It was inevitable that man should learn that the flesh of such animals, confined and well fed, was tenderer, fatter and altogether more appetizing than that of wild game. Land had little or no value to primitive man—there was too much of it. The first wealthy were those who possessed large flocks. Naturally meat became an important article of diet among pastoral peoples. It was so in the early days of our own era on the western plains of North America, where stock-raising was the principal industry. But the cattle man ate beef, the sheep man mutton, as the meat most available to him, not because beef was a better food for the one or mutton for the other.

We shall not speculate as to how or when man acquired his taste for cooked food. The use of fire antedates recorded history. The discovery that by cooking

the tough flesh of wild game could be made easier to chew, and perhaps to digest, must have been a great boon to mankind. But fire is not the only means utilized to soften food. Roubakine relates that the Kalmouks and the Kirghizes, who live in the steppes of western Europe, where the only fuel is dry grass and the dung of camels, place strips of meat on the backs of their horses, between the skin and the saddle. After a day's ride the meat is considerably softened. This custom did not arise from a perverted or depraved appetite, but from a lack of fuel. The practice of allowing meat to hang for some days to ripen, that is, to be softened by the digestive enzymes of its own juices, is well known.

But the introduction of cooked food must have created somewhat of a social problem. We can imagine that tremendous resistance must have opposed it at first. It could be argued, and doubtless was, that such soft pabulum would result in a tribe of mollycoddles, with inferior physique and stamina. There may have been taboos against it, and food riots, as there were in Europe in comparatively modern times, following the introduction of the potato and attempts to compel its use. More interesting to us, however, is its effect on the dietary habits, that is, the instincts of man as related to the choice of food. Certainly it could not have come about abruptly. All cooked foods taste altogether different from the same foods in the raw state. An entirely new set of criteria (instincts) must become firmly established, so firmly indeed that civilized man would not consider eating raw flesh under any circumstances and eats raw vegetables with considerable reluctance. This change from raw to cooked food is another argument for our theory that dietary instinct is a distrust for the unknown, for those things of unfamiliar taste, and nothing more.

We now come to consider what effect religion (or superstition) may have had in the formation of dietary habits. All primitive religions are religions of sacrifice. Man feared his gods and placated their wrath or won their approval by the sacrifices which he placed on the altar. Naturally, no god could command the respect of his subjects if he could be appeased by inferior offerings. It is the choice of the flock, and the best parts of the slaughtered animal, that are to be placed on the altar. This admonition is clearly set forth in the first chapter of the book of Leviticus. The priests who tended the altars took for their own sustenance from among the sacrifices placed there by the faithful. Thus the priests had a double motive in enforcing the laws of their religion as to sacrifice. First, the authority and superiority of the gods could only be maintained by the insistence that they could accept only the choicest and best. Second, the priests, for their own selfish interests, would insist on the same thing. The authority of the priests to take for themselves of the food placed on the altar is set forth also in the book of Leviticus.

The parts demanded, in most such cases, were the entrails and the blood. This leads us to the conviction that internal organs and blood may have been once highly esteemed as articles of diet. But, their use being proscribed, man came, throughout the generations which followed, to look upon them as not fit for food. To show that this position is not sound physiologically, we have only to cite the experience of keepers of zoological museums. Lions and tigers fed only on muscle flesh sicken and die, but if the internal organs of the slaughtered animals are added to the menu, they thrive. The feral beast which, beset by pangs of hunger, brings down a deer, tears open the carcass and disembowels it, disdaining to touch the muscular tissue until all else has been consumed.

The rite of burnt offering disappeared with advancing civilization, but the dis-

taste for liver, kidney, stomach and other glandular tissue persisted. The ban of religion, being lessened or removed, however, man had no scruples against eating them if need required. The pioneer settler in America made sausage of the liver and blood and other, to him, less desirable parts of the butchered animal. He pickled the stomach into tripe, and cleaned the intestines for sausage casings. Sustenance was scanty and hard to come by. He dare not discard any part of the carcass that could be put to use. Nevertheless, the distaste for glandular organs is extremely prevalent. Relatively few people to-day eat liver, sweetbreads or kidney stew. And to complete this remarkable picture of the cyclical course of a distorted dietary habit or instinct, we need the findings of modern medical science that the liver is a wonderful storehouse of minerals and vitamins not found in flesh and that the mucosa of the stomach supplies a factor widely used in the treatment of pernicious anemia.

Religions of primitive man were also called into play to reinforce the taboos previously mentioned as arising from division of labor between sexes or between people of different ages. Certain forms of food were forbidden by religion for reasons, possibly economic, possibly of other origin. A whole series of animals was forbidden as food to the Jews. We can readily understand why such a proscription should run against the camel, an important beast of burden. The animals permitted to be eaten were those with parted hoof, and which chewed the cud. This practically limited them to cattle, sheep and goats, and, being a pastoral people, it is quite reasonable to believe that the live-stock industry would strive to utilize religion to stamp out the competition of cheaper forms of meat, the hog and the rabbit, just as, when the cattle barons ruled the great plains of North America, the introduction of sheep was contested with every legal and illegal method, including arson and bloodshed. The ranch owner refused to eat mutton or permit it to be served to his family or guests, not because he considered it less wholesome and nutritious than beef, but because to him the entry of sheep-raising into the country meant economic loss or even ruin.

With our knowledge of to-day, we could justly ascribe the proscription of pork to a desire to protect the people from the dangers of trichina, that of the rabbit against those of tularemia, but by no stretch of imagination can we impute a knowledge of these parasites four thousand years ago nor a reasoning power that would connect an illness with the eating of infected meat days or even weeks before.

Both the Jews and the Mohammedans were also forbidden to eat the meat of animals which died other than by slaughter, but strangely enough, the Jews were charged to give it to travelers or sell it to foreigners, whose nutritional needs were doubtless different from their own.

Let us next consider the distribution of man on the face of the earth, and what effect it may have had on his dietary habits. It is simple to trace the effects of temperature, but some other geographical influences may be more obscure. The polar Eskimo, residing in regions where vegetation is absent or scanty, subsists almost entirely on meat and fat. Stefansson, who has spent a total of nearly five years in living with the Eskimos, reports that their native diet is composed entirely of raw and boiled fish, the game having been exterminated by the intensive hunting that supplied meat to the whaling fleets of fifty years ago. In spite of this seemingly monotonous diet, he did not observe a single case of rickets, scurvy or carious teeth. That a carnivorous diet can maintain members of the Caucasian race in health and vigor for con-

siderable periods of time has also been demonstrated by Stefansson, who, under the observation of scientists of the Russell Sage Foundation, lived for a year on meat and fat alone. Tropical peoples subsist to a greater extent on vegetables and fruits. Is this because the requirements of life in the tropics do not call for the specific dynamic action of a high-protein diet or because fruits and other products of vegetable origin are easy to obtain in tropical regions, but practically unavailable in arctic areas? Is this difference in dietary habits due to a difference in physiological requirement or a difference in the kind of food most available? We incline to the latter view.

An interesting sidelight has to do with the use of salt. According to Morse, the normal daily human urinary excretion of salt is fifteen grams (half an ounce), and it is said that man is the only animal to have acquired such an appetite for salt as to eat it in excess of his daily needs. Salt was so highly esteemed by the ancients that the wages of Roman soldiers were paid in this commodity, hence the word *salarium* or salary. Nonetheless, the Eskimos, far from using salt, actually have a distaste for it. Stefansson states that in his first winter with them he was so beset by hunger for salt that he boiled down some sea-water, but that when he added the resulting brown powder to the pot of cooking fish, his Eskimo hosts politely declined to partake. He also reports that the deer in Maine do not crave salt, while those of Minnesota do. To me, it appears probable that men and animals subsisting largely on grain and vegetables, which contain an excess of potassium over sodium, as compared with the composition of the tissues and fluids of the body, would require salt to correct this inbalance, while those of purely carnivorous habits would require less or none. It may be that the herbage in Maine and other coastal regions is enriched in salt by the spray from the waves of the sea, blown inland and deposited on the foliage or in the soil. I was interested to observe, on a visit to Itasca State Park in Minnesota some years ago, that the primitive outhouses erected for the convenience of visitors had had their foundations almost entirely eaten away by hedgehogs and other small animals, who gnawed away the wood to get the salt from human urine which impregnated it. The craving for salt doubtless has a sound physiological basis among animals and men subsisting largely on products of plant life, but why does man take so much of it that he excretes half an ounce daily? It is common for physicians to limit the salt intake of patients suffering from arterio-sclerosis or hypertension, but on what grounds is not clearly evident.

The banana, a food of considerable importance in the West Indies, had to await the development of cold storage in transportation before it could be widely used on the continent of North America. Even yet the cost of bananas in the north central states is so high that they can not be used as a staple food. The pineapple, so commonplace in the Hawaiian Islands, had to wait for the development of the canning industry before it could be considered other than as a great luxury in the United States.

Geography has had an important part in developing the dietary habits of man. Wheat, the great bread-stuff of the American people, does not thrive in semi-tropical climates. Corn, on the other hand, is a tropical plant which has made its way north. Corn plays a much more prominent part in the diet of natives of South Carolina and Georgia than does wheat. Still more interesting is the story of rice, which was introduced early into Carolina and the growing of which developed into a great industry. No rice is grown in this region now, nor has been for many years, but it is still one of the most important

staple foods, seen daily on the tables of all native South Carolina families. Inventive genius devised a way to scour the bran coat off of rice, rendering it more pleasing to the eye and easier to masticate. For this reason polished rice came to be preferred, but with disastrous results to some Oriental peoples, who subsisted quite largely on rice and fish. A mysterious multiple neuritis (beri beri) took its toll, until about 1908, when two Dutch physiologists, Eijkman and Grijn, demonstrated a vital factor (vitamin B) in the bran that was scoured off and thrown away or fed to pigs. The sense of taste was inadequate to warn man that the new product was inferior to the old; in fact, he liked it better. He ate rice because his parents had eaten rice and because it was available to him at low cost. Grijn demonstrated effectively the fallacy of polishing rice, but none but polished rice is sold in the markets of the world to-day.

One might enlarge still farther upon this matter of geography, but it hardly seems necessary. It is, however, intimately bound up with that of economics, as we shall now see. The easiest and cheapest way for primitive man to obtain meat was the hunt. There was usually plenty of game if he could get it. With the increase of population and improvement of weapons, game became scarce, and it was easier to raise his meat than to hunt for it. With still further increase in population, land became of more value, and when it became possible to sell or barter grain to others, some parts of the soil could produce more returns in wheat or corn than they possibly could in cattle. Naturally, people inhabiting such areas came to depend largely on tilling the soil, and became more vegetarian in their habits than those who dwelt in rough, broken or arid regions, regions which would not yield a profitable crop, but could furnish pasturage to animals. In fact, this increase in population has worked to further increase the value of land in some localities, to a point where it could not possibly be used to produce live stock.

Roubakine reminds us that in Russia, before the revolution, the amount of land available for agriculture had remained the same for an entire century. But population having increased rapidly, the individual parcels had become smaller and smaller, and it became increasingly difficult for the Russian peasant to feed and clothe himself by the products of his own land, and almost impossible to feed live stock. It takes considerably more acreage to feed a goat or a bullock than to feed a man. Nevertheless, although he must have some animals to do his plowing and carry his burdens, he can not afford to raise his calves or his lambs. The Russian peasant is to all practical purposes a vegetarian, eating on the average less than twenty pounds of meat per person per year, and this in the form of veal or lamb. This should not lead us to conclude that such a low meat consumption is physiologically optimal or that the flesh of calves and lambs is more nourishing than that of beeves or sheep. He eats what he can get, not what he would if he had free choice. Even to-day in Germany, the farmer can sell all the grain he produces at a good price, but there is a scarcity of meat because most of the grain that can be raised is needed to feed the people themselves, with very little surplus for live stock.

To the Hindu peasant his goat, who carries his burdens, works his land and feeds his children with her milk, has an economic value far greater than if he were to kill her. In fact, his religion forbids him to do so. For similar reasons the cow is sacred in India. This paucity of land is still more acute in China, where the peasant never gets enough to eat. Meat is almost an unknown luxury to him, and what meat

he does get is pork, which can be produced more economically than beef or mutton. The opposite side of the same picture is revealed in pastoral peoples of Turkestan, one of whom finds it easy to slaughter a lamb or sheep from his flock to regale his family or guests, but extremely difficult to provide grain or bread for them.

But food habits are so slow to change that emigrants carry with them into their new habitat their accustomed likes for national dishes, and abandon them only under force of necessity and with great reluctance. Norway and Sweden are rough and mountainous countries, not particularly suited to agriculture, but, on account of their extensive seacoast, well adapted to fisheries. Fish has a prominent place in the dietary of Scandinavian peoples: they have learned various ways of smoking, salting, pickling and otherwise preserving it, as well as ways of preparing it for the table unknown in other lands. Wisconsin and Minnesota are largely settled by Norwegians and Swedes, who, despite the scarcity of fish in this inland area, still maintain their esteem for it, so that tremendous quantities of smoked, dried or salted fish are imported and consumed by them. Indeed, the ordinary country grocery store in Minnesota offers a wide variety of foods unknown and unobtainable in South Carolina.

Let me refer again to the economic value, as contrasted with the nutritive value, of an article of food. To a baker in the city, bread is an article of commerce, which he makes and sells in order to provide for his needs and those of his family. Its value to him as an article of commerce depends on the price it will bring. Its value to him as an article of food depends on its chemical composition and digestibility. The two measures of value are quite different, and yet it seems almost inevitable that they become confused or merged into one idea in the mind of the baker. The fancy breads and cakes which command a higher price appear to him more desirable as articles of food also. Price and quality are often synonymous, but more often it is scarcity, not value as food, which determines price. Those cuts of beef which are more sapid and tenderer, easier to cook and to chew, are more extensively sold at a higher price than the chuck and brisket, notwithstanding there is no commensurate difference in nutritive value. A highly prized article of food, one that is served on special occasions, is almost invariably an exotic one or one the scarcity of which makes it expensive. We rate its value not by calories, but by cost.

There is still another side to the influence of economic consideration in determining food habits. Those who produce food, the world over, are people of very modest income. Thrift is a necessity with most of them. If then, for example, potatoes are dear and turnips are cheap, the potatoes will be sold and the farmer's family fed on turnips. Holland, one of the principal dairying countries of the world, imports large quantities of oleomargarine, but sells her butter to England. The market value of what he produces is so high that the producer buys a cheaper substitute for himself. I have visited the homes of immigrant farmers in the Dakotas, where, notwithstanding that a considerable portion of the family income came from the sale of cream, no milk was given to the children. The reason, economic of course, is obvious. Every fresh cow meant a calf, which, if raised to maturity, had a definite cash value. The cream was separated and sold, the skim milk fed to the calves and young pigs. Children had no market value, nor any productive value until old enough to follow the furrows. Inevitably most such children grow to maturity with the idea that milk is suitable food

for calves and pigs, not for humans, and thus a dietary habit (instinct) is created.

Modern commerce brings to our doors many things unknown to our grandfathers or, if known at all, were not considered as things to be eaten. Always, the introduction of a new foodstuff makes slow progress. Attempts have been made to force matters by laws or by royal decrees. It was so in Europe, following the discovery of America and the introduction of the potato. More food could be grown on an acre as potatoes than as wheat. The ruling classes attempted to compel the growing of potatoes, with resultant riots in France in the eighteenth century. Always in every land and every time, people are suspicious of new and strange foods. It is only epicures who are venturesome in trifling with the sense of taste.

Commerce in foodstuffs has been stimulated by the invention of new ways of packing, processing, preserving and handling them, until now it has become one of the major industries. Refrigeration in storage and transit brings to the table of middle-class families in New York beef from Argentina, bananas and avocados from the West Indies, oysters from Maryland and shrimp from New Orleans. Sterilization in sealed containers makes available throughout the year and at moderate cost seasonal fruits and fruit juices and green vegetables. The mere fact that these canned and bottled products are available throughout the year naturally stimulates their consumption, but availability is not the only, nor indeed the most persuasive factor. One needs only to pick up any current woman's magazine to see beautifully illustrated and alluringly worded advertisements for canned tomato juice, canned pineapple, peas, spinach and what-not. These advertisements always stress nutritive and health-promoting properties, but no one will believe that they are prompted by so altruistic a motive. Commerce and the desire for profit bid fair to revolutionize the eating habits (instincts) of the American people, whether for good or ill only the nutritionist can say. Unfortunately, to such a voice in the wilderness there are few hearers.

An extremely interesting example lies in the use of sugar. The first recorded description of sugar is to be found in the writings of Theophrastus, and even up to the middle ages it was considered as a medicine and sold by apothecaries. With the invention of cheaper and better methods of extraction and refining, sugar became cheapened until it could be used as a staple foodstuff. This gave a tremendous stimulus to the cultivation of the cane and the beet. Advertising and ingenuity in developing new confections and other dishes containing sugar now came into play in order to further increase consumption and profits. According to government statistics, the per capita consumption of sugar in the United States has increased from about 70 pounds in 1900 to 112 pounds in 1926. This latter figure corresponds to 139 grams or about 570 calories per person per day, about one fifth of the total energy consumption. What reliance, I ask, can be placed on an instinct which leads us to derive so large a fraction of our nutriment from the most highly refined carbohydrate known, a substance which builds no muscle or bone, yields no vitamins, and the excessive consumption of which is looked upon with grave suspicion by the medical profession?

Although sugar consumption has increased 60 per cent. since the beginning of the century, the total energy intake has not increased appreciably. We eat about as many calories per day as our grandfathers did. Sugar has replaced something else. Washington Platt has made a careful study of data collected from government reports and from other sources, and reports that during this same period the consumption of

meat decreased 6 per cent., that of wheat flour and bread 30 per cent. and that of corn meal and flour 80 per cent. The consumption of fresh and canned fruits and vegetables has increased. Oranges have doubled in fourteen years. Dairy products have also increased, although they fell off sharply during the depression. It is a strange coincidence, and must be disturbing to those who hold to the reliability of instinct in the choice of food, that those products most intensively advertised should show increasing consumption, while those foods which have most largely nourished and sustained man for centuries, meat and grain, show losses. Is our eating ruled by preference or propaganda?

Finally, let us ask if the theory that man possesses an instinct which leads him to select those foods which most satisfactorily satisfy his needs is confirmed to any degree by the sciences of chemistry and physiology. These two branches of learning have by their union brought forth the young science of nutrition, which, using small laboratory animals as test-tubes has made quite substantial progress in the last quarter century. We know the importance of the fat soluble vitamins A and D, the first for growth and maintaining the integrity of the tissues, the second in the growth and development of normal bones. Vitamin A, or its precursor, an orange-colored organic pigment known as carotene, is especially abundant in carrots and green plants. The outer dark green leaves of cabbage and lettuce contain much more of it than the tender inner leaves. Furthermore, a considerable part of the carotene of plants is destroyed or inactivated in the process of cooking in an ordinary open kettle. Human taste apparently can not detect differences in this respect—we prefer white cabbage and lettuce hearts, and thoroughly cook all our greens.

Greenland was colonized by Eric the Red in 985, but in 500 years the people had disappeared. Study of skeletons recently disinterred at Herjolfsness by Hansen has shown evidences of marked rickets. Can it be possible that rickets, due to lack of vitamin D or calcium, or both, was responsible for the decline of this colony? A diet almost exclusively of grain would fail in calcium requirement as well as vitamin D. But the liver oils of many marine fishes are rich in the vitamin, and the Scandinavian peoples are notable fish eaters. The production and use of leafy vegetables would have supplied any calcium lack. A reliable instinct should have led inevitably to the use of greens and fish livers or liver oils, and saved the colony. It is the consensus of opinion that many people are obtaining less than optimal amounts of the water-soluble vitamins, yet sources of these are so abundant that a rational dietary instinct would lead inevitably to their selection.

Goiter is extremely common among the inhabitants of central North America, due primarily to iodine lack. Not having been accustomed to sea food, these people eat it but rarely, even though modern commerce has made it available. One would think that so outstanding a dietary deficiency would have produced a craving for iodine bearing foods and made fish and oysters even more popular than at the seashore. Although the iron and calcium content of agricultural crops may vary several hundred per cent., according to the type of soil on which they are grown, no taste can or ever could, detect the difference, and deficiencies of these elements in the diet in some localities are common.

Nor can I close without a word regarding certain misguided pseudo-scientists who are endeavoring to lead us in the choice of our food. Bernarr Macfadden, writing editorially in *Liberty* for January 25, 1932, said: "One can live on wheat indefinitely if the whole grain is used. It nourishes the body

throughout its every part." And this, notwithstanding the observation of McCollum, of a number of years standing, that heifer calves fed exclusively on wheat and wheat straw failed to thrive. Alonzo Taylor has shown that war bread is actually more expensive than white bread as a source of available energy, because the excessive roughage speeds up intestinal movement to a point where absorption is very inefficient. The amount of indigestible roughage desirable in the human digestive tract has, according to Cowgill, rather well-defined limits. The fad for eating bran has nothing to commend it. I scarcely need mention that the idiotic teaching exemplified in the Hay system of diet that certain food combinations, such as meat with bread or potatoes, are harmful when taken together, has been exploded by more than one reputable scientist of recognized standing.

Finally, the theory that civilization has dulled our native instinct in the choice of food or rather that this dulling is resulting in less adequate nutrition is refuted by certain very pertinent statistics. The second and succeeding generations of immigrants to the United States from Central Europe or Japan are taller, have larger frames and are more robust than their parents. The higher standard of living, with its wider variety and choice of food, finds immediate response in the physical development of these people.

To summarize, I have tried to set forth that the dietary instincts or habits of man are an outgrowth of certain *mores* which had their origins in the beginnings of tribal life, influenced in their development by religion, by geographical habitat, by climate, by commerce, by modern industrial and inventive genius and by advertising. I have shown that food likes and dislikes are taught in childhood, and though they may be slow to change, they do change as influenced by the factors mentioned above, and that dietary instinct is only a distrust for the unknown or for those articles of provender for which we have not acquired familiarity. The contributions of chemistry and physiology to our knowledge of nutrition, valuable as they may be to the live-stock industry, have up to this time played a very minor part in directing the eating habits of the human species.

FUSIBLE ALLOYS

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FUSIBLE teaspoons have provided mirth for many. As the unsuspecting guest starts to stir his hot tea he suddenly finds himself stirring air with a stub of a handle, while the molten spoon mirrors his chagrin from the bottom of the cup. These "fusible" spoons are often thinly plated with silver to further allay any suspicions the guest may have. This humorous use of fusible alloys has been practised ever since the discovery of these interesting but forgotten alloys which melt below the temperature of boiling water. There exist, however, a number of more important and unique uses for these low melting alloys, most of which are dependent on the very low melting points.

Fusible alloys have been defined by Law[1] as alloys melting below the melting point of tin. The four common metals used in preparing the alloys are often themselves called fusible *metals* because of their relatively low melting points. They are listed below.

TABLE I

THE COMMON FUSIBLE METALS

Name	Melting point in degrees Centigrade
Tin	231
Bismuth	271
Cadmium	321
Lead	327

To these four metals may be added mercury, which is often used to depress the melting point of the alloy still further.

It is indeed surprising that from combinations of these four metals, each alone melting above 200° C., it is possible to obtain an alloy which melts in hot water (from 70 to 100° C.). However, the phenomenon is a common one. Just as salt added to water lowers the freezing point of water, so bismuth added to molten lead lowers the freezing point of lead. This phenomenon will occur only if the two metals form neither compounds nor solid solutions with one another. The phenomenon is illustrated in Fig. 1 for two ideal metals A and B. As metal

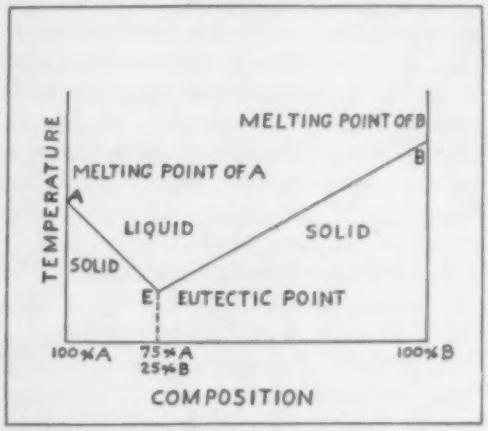

FIG. 1. TEMPERATURE-COMPOSITION DIAGRAM FOR AN IDEAL EUTECTIC ALLOY.

B is added to molten metal A, the freezing point falls along line AE. As metal A is added to molten metal B, the freezing point falls along line BE. The point E is the lowest freezing point attainable with any combination of metals A and B. It is known as the eutectic point. The composition of the alloy which melts or freezes at this point is known as the eutectic composition. Eutectic alloys are, therefore, alloys having the lowest melting points attainable with any combination of the metals concerned. If a third metal is added to the "binary" alloy a "ternary" eutectic alloy may be obtained with a still lower melting point. The addition of a fourth metal may produce a "quaternary" eutectic alloy with a still lower eutectic point.

[1] Law, "Alloys and Their Industrial Applications."

The various binary eutectic alloys of the four fusible metals have melting points ranging from 125° C. for bismuth and lead to 249° C. for lead and cadmium. The melting points of the ternary alloys range from 91.5° C. for bismuth, lead and cadmium to 145° C. for lead, tin and cadmium. Only one quaternary eutectic alloy is possible. It melts at 72° C.

History of the Fusible Alloys

Ternary alloys of lead, bismuth and tin melting in boiling water have been known for several hundred years. These alloys were usually named for their discoverers. Most of them were not eutectic alloys, and many of the reported melting points have been found to be erroneous. Table II shows some of the more common alloys, together with reported melting points.

TABLE II
Common Fusible Alloys

Name	Composition Parts by weight					Reported melting point degrees Centigrades
	Bismuth	Lead	Tin	Cadmium	Mercury	
Newton's metal ...	8	5	3			94.5
Rose's metal	5	3	2			91.6
D'Arcet's metal ..	50	25	25			91.6
Lichtenberg's metal	5	3	2			91.6
D'Arcet's metal with Mercury ...	50	25	25		250	45.0
Wood's metal	50	25	12.5	12.5		65.0
Lipowitz alloy	50	27	13	10		65.0

Robert Boyle[2] in 1662 mentions the use of an alloy consisting of bismuth two parts, lead one part, tin one part and mercury ten parts as a "fluid amalgam, which being moved backward and forward in a clean glass vessel leaves a train behind it, adheres to the glass and foils or silvers it. It is therefore used in foiling the inside of glass globes." While bismuth was not clearly distinguished from lead previous to 1737, it seems likely that Boyle recognized the difference. Rose's metal was first prepared by Valentin Rose the elder about the middle of the sixteenth century. D'Arcet's metal was discovered about the same time. It seems likely that the later alchemists used some of these fusible alloys in their attempts at transformation.

Black[3] in 1803 mentions Newton's metal, which becomes "fluid at a temperature something below that of boiling water." Black also mentions a proposed unique use of the alloy dissolved in mercury to "dissolve lead balls lodged in a wound" because "when dissolved in mercury it forms more fluid amalgams with other metals, particularly with lead than ordinary." He goes on to say, "whether this would answer the purpose I cannot positively say because the bismuth or part of it, separates in the form of a powder while the lead dissolves which might possibly prove inconvenient."

The use of cadmium to produce quaternary alloys melting below 90° C. did not come till some time after the discovery of cadmium by Strohmeyer in 1817. Wood's metal was first reported by Wood in 1869. For some time, it was considered to be the quaternary eutectic alloy. However, it has been shown by a number of recent investigators that Lipowitz alloy is more nearly of eutectic composition than Wood's metal. Melting points ranging from 60° C. to 80° C. have been reported at various times by various investigators for these two alloys. As a matter of fact, since the two alloys are so nearly of the same composition they should both melt at the eutectic point. The writer[4] has recently shown that these alloys do both melt at the same temperature. A number of recent investigations have placed the freezing point of the eutectic alloy at close to 70° C.

Uses of the Fusible Alloys

The uses of the fusible alloys have been many and sundry. Alloys rich in bis-

[2] Robert Boyle, "Treatise on the Usefulness of Experimental Philosophy," 1662 (about).

[3] Joseph Black, "Elements of Chemistry," 1803.

[4] S. J. French, *Jour. Ind. Eng. Chem.*, 28: 111–112, 1936.

muth were early used in type metals and for making impressions of wood carvings. Bismuth gives to the alloy the property of expanding on freezing. Hence, sharp impressions are obtained.

D'Arcet's metal found early use for making anatomical molds. The metal was poured around the specimen and the fleshy parts of the specimen later dissolved out with caustic solutions.

Tin and bismuth alloys, because of the sonorous tones produced when struck, were often used in bell metals. Many of the alloys find use as low melting solders for tin, lead and pewter articles. Bismuth has even found use in the past as an adulterant of mercury. A number of the alloys have found use as baths for tempering steel instruments.

During the nineteenth century, a number of the alloys found use as safety plugs on high pressure steam engines. When the temperature reached a dangerously high point, the plug melted, releasing the pressure. However, since the alloys used were non-eutectic alloys, a gradual change in composition took place on long exposure to temperatures slightly below the melting point. The melting point of the alloy rose and the safety plug became a source of danger. The use of these plugs was soon discontinued.

In 1918 Steinmetz[5] suggested the use of eutectic alloys for calibrating thermal instruments, since the melting and freezing points of eutectic alloys are fixed and sharp.

One of the important modern uses of these alloys is for making seamless vessels. This was particularly important during the war, when gas tanks of unusual shape were needed for aeroplanes. The molten alloy is first made into the desired shape in a mold. Copper is then plated over the alloy to the desired thickness. The whole is then placed in a bath of hot water. The alloy melts and is poured out of the copper vessel.

[5] C. P. Steinmetz, *Jour. Am. Chem. Soc.*, 40: 96–100, 1918.

The best known modern use is in the manufacture of automatic fire sprinkling systems. Openings in the pipe line at various intervals are sealed with metal stoppers held in place by a rod of fusible alloy. At a given temperature the alloy melts, releasing the stopper, and the sprinkler system starts. Fire doors are often held open by a bit of fusible alloy. On melting, the alloy releases the door, which closes by gravity. A number of other fire control and thermal instruments involve uses of the alloys.

Physical Properties of the Quaternary Alloys

Little published data have appeared on the physical properties of the quaternary fusible alloys. Budgen[6] has studied the tensile strengths, hardness, flexibility and grain structure of some twelve quaternary alloys. His results are summarized below.

The tensile strengths are rather low, being about one fourth that of copper and slightly better than that of tin. Elongation in the case of the eutectic alloy was 20 per cent. However, the elongation depended largely on the rate of loading. When 16.6 per cent. of mercury was present in the alloy, the tensile strength was greatly reduced. All the alloys split on gentle hammering or cold rolling. When loaded rapidly all the alloys possessed the property of extreme brittleness. When loaded slowly they were very flexible. In this respect, they resemble pitch.

Alloys containing the greatest proportions of bismuth showed the greatest degree of hardness. The Brinell hardness number of the eutectic alloy was 18, almost as low as that of pure annealed aluminum.

In grain structure the eutectic alloy and most of the others showed a fine-grained fracture. In micro-examination they showed the presence of four struc-

[6] N. F. Budgen, *Jour. Soc. Chem. Ind.*, 43: 200–203T, 1924.

tural constituents, those approaching eutectic composition showing the finest crystals. All tended to corrode rather rapidly when kept molten under water or liquid paraffin.

Other Fusible Metals

Mercury is the only other common metal of low melting point. It is sometimes added to quaternary alloys to produce quinternary alloys melting below 70° C. However, the products obtained are somewhat unsatisfactory. The tensile strength and hardness fall off rapidly. Melting points are rather indefinite. The alloy becomes pasty, then granular and hardens to a granular mass, losing much of the normal metallic property. Eutectic alloys are not formed.

There exists another group of low-melting metals which because of their limited supply have not yet found use commercially in fusible alloys. These metals are gallium, indium and thallium. Table III shows a section of the Periodic Classification of the elements, indicating the positions and melting points of these rare metals together with the common fusible metals. Interestingly enough, all these fusible metals are found closely grouped in the periodic table.

TABLE III

A Portion of the Periodic Table Showing the Fusible Metals* and Their Melting Points in Degrees Centigrade

Copper 1083	Zinc 419.4	Gallium 29.75	Germanium 958	Arsenic 500(s)
Silver 960	Cadmium 321	Indium 155	Tin 231	Antimony 630
Gold 1063	Mercury −40	Thallium 303.5	Lead 327.5	Bismuth 271

* The fusible metals are enclosed by the double line.

The rare metals gallium, indium and thallium are, themselves, of considerable interest. Because they are high priced they have found little use, and because they have found little use they are high priced. They are rather widely distributed, but few sources contain sufficient quantities to make the recovery economically practical with so little demand. As uses are found, the supply can be materially increased and prices decreased.

Twelve years ago, a gram of indium was unobtainable in this country. The metal was priced at ten dollars a gram (about $300.00 an ounce) with few purchasers. To-day, thanks principally to the work of Mr. William Murray,[7] indium is cheaper than gold. It can be purchased in small lots at one dollar a gram and in larger lots at considerably lower prices. Indium was first discovered in 1863 by Reich and Richter. Incidentally, Reich was a student of Strohmeyer, the discoverer of cadmium, and was looking for thallium when he saw the strong indigo blue line so prominent in the spectrum of indium. The element was named for its prominent spectrum line. The metal, itself, is soft and lustrous and remains untarnished in air. Alloyed with silver it gives an untarnishable surface.

Gallium was discovered by Boisbaudran in 1875 and was named in honor of France. It was found to be present in Oklahoma zinc blends in small amounts by F. G. McCutcheon in 1915. It is lighter than indium and somewhat harder and does not tarnish readily. It melts quickly when held in the hand and will melt on a hot summer day. It is still among the very rare metals, retailing at eight dollars a gram (about $240.00 an ounce). So far, it has found no industrial uses and has been but little experimented with because of its high price.

Thallium was first recognized by Sir William Crookes in 1861 by the bright green line of its spectrum. By 1862 he had isolated the new heavy metal resembling lead. The metal is soft and tarnishes quickly in air. It has found

[7] S. J. French, *Jour. Chem. Ed.*, 11: 270–272, 1934.

few uses since the more abundant and stable lead serves most purposes better. Some is used in making refractive optical glass. Like lead, the metal and its compounds are poisonous. The use of thallium compounds in depilatories has resulted in some serious illnesses. The metal is the cheapest of the three by far, retailing at less than four dollars an ounce.

Quinternary and Hexernary Alloys

Quinternary and hexernary alloys, containing the three rare metals together with the four common fusible metals, have recently been prepared by the writer.[8, 9, 10, 11] Such alloys have not previously been reported in the literature, probably because high prices discouraged experimentation.

Thallium is not very soluble in the quaternary eutectic alloy and apparently does not form a quinternary eutectic alloy. However, the addition of some 6 per cent. of thallium to the quaternary eutectic alloy produces an alloy freezing at 66° C. or about four degrees below the freezing point of the quaternary alloy. With further addition of thallium, the freezing point rises rapidly.

Indium appears to be completely soluble in the quaternary eutectic alloy. The melting point of the alloy falls rapidly as indium is added. The lowest melting point, 46.7° C., is obtained with an alloy containing 18 per cent. of indium. The alloy freezes sharply at 46.5° C. The sharp freezing and melting points, together with the type of cooling and melting curves obtained, indicate that the composition of the alloy comes very close to the eutectic composition.

The properties of the indium alloy resemble those of the quaternary alloy very closely. The indium alloy is, however, less easily corroded in air and water. Such an alloy, though more costly, has many advantages over the mercury alloy, since it retains its metallic properties.

Thallium is but slightly soluble in the indium alloy, and eutectic hexernary alloys containing both indium and thallium together with the four common fusible metals are not formed. As a matter of fact, the melting points of such alloys rise rapidly as thallium is added.

Were gallium completely soluble in the indium quinternary alloy it should be possible to obtain hexernary alloys melting considerably below room temperatures. However, such does not seem to be the case. While work on these alloys is still incomplete, the present evidence indicates that gallium is but slightly soluble in the indium alloy. The presence of about 1 per cent. of gallium lowers the melting point of the alloy about five degrees, to 41.5° C. Further additions have but little effect. More complete data on these alloys will be ready for publication soon. Gallium probably forms eutectic alloys with indium and zinc, for McCutcheon discovered the presence of gallium in the Oklahoma zinc ores by noting beads of liquid metal resembling mercury on the surface of a leady residue from the redistillation of zinc. On analysis, this liquid alloy proved to contain gallium, indium and small amounts of zinc.[12] An alloy containing 12 per cent. tin and 88 per cent. gallium has been reported melting at 15° C.[13] It seems likely therefore that a binary alloy of indium and gallium

[8] S. J. French, *Jour. Ind. Eng. Chem.*, 27: 1464, 1935.

[9] S. J. French, "The Effect of Thallium on the Melting Point of Indium-Lipowitz Alloy," "Metals and Alloys" (in press).

[10] S. J. French and D. J. Saunders, "The Effect of Thallium on the Melting Point of Lipowitz Alloy," "Metals and Alloys" (Jan., 1936).

[11] Unpublished data obtained by the author.

[12] "Gallium, Germanium, Indium and Scandium." Information circular 6401, U. S. Bureau of Mines, November, 1930.

[13] N. A. Pushin, S. Stepanovic and V. Stajic, *Zeits. Anorg. Allgem. Chem.*, 209: 329–34, 1932.

could be prepared melting below 0° C. The cost of such an alloy would be prohibitive. From the evidence reviewed it seems unlikely that gallium would form a quinternary eutectic alloy with the common quaternary alloy.

Possible Uses of Quinternary and Hexernary Alloys

While these very fusible alloys containing indium and gallium are too new to have any commercial uses as yet, great interest has been manifested in them. It seems likely that they will find their greatest field of usefulness in thermal controls of various types.

Since the melting point of the indium alloy is so little above normal body temperature such an alloy may find use for making casts or impressions of features. The body can come in direct contact with the molten metal. Sharp finger print impressions can be made in this manner. The alloy after hardening can be plated with copper, then melted off for further use. The use of the alloy for such purposes will depend somewhat on the expansion or contraction of the alloy when it freezes. While these properties have not yet been fully determined, superficial examination indicates a slight expansion on freezing. To obtain alloys melting down to body temperature, small amounts of gallium or mercury may be added.

Alloys melting a little above body temperature might also find use in surgical casts. For this purpose the alloy would have to be impregnated in a cloth matrix. The warm flexible material could be wrapped around a broken leg or arm and allowed to set. If it were desired to change the position of the member, hot water bottles would melt the cast and permit the change to be made.

Until the prices of the rare metals are still further reduced, uses of the alloys will be restricted to fields in which cost is of small importance or in which the alloy may be used over and over. In small lots, the indium alloy costs, to-day, close to five dollars an ounce. One per cent. of gallium added raises the cost to more than seven dollars an ounce. The more common alloys melting above 72° C. cost, for the ingredients, less than ten cents an ounce. Little is known, as yet, about the physical properties of the quinternary or hexernary alloys.

IN QUEST OF GORILLAS

XI. GORILLA CHILDREN

By Dr. WILLIAM KING GREGORY

CURATOR OF COMPARATIVE ANATOMY AND OF ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY; PROFESSOR OF PALEONTOLOGY, COLUMBIA UNIVERSITY

UPON returning to Yaoundé we called at once at the American Protestant Mission and found that, although Mr. and Mrs. Johnston were then away, they had left a very kind letter for us, inviting us to stay at their home and to return there whenever we happened to be in Yaoundé. The Negro steward of the Mission then showed us to two very pleasant guest rooms and our own three "boys" (two of whom had been Mission boys, recommended to us by Mrs. Johnston) went into the kitchen and prepared our meals. Through the windows and door of the dining room we could look down past the well-kept flower garden over a fertile valley to the bold lumpy hills in the distance. We thought it spoke very well for the good influence of the Mission that Mr. and Mrs. Johnston could go away for several weeks and leave everything apparently wide open and solely in the care of their Mission boys. Moreover, as far as we could see, the church services, schools and farming work were going on quite according to schedule.

Early the next morning I heard the measured sweep of a Presbyterian hymn tune rising steadily from the chapel near-by—an ancient Protestant hymn sung with strange accents and exotic voices but with great sincerity by black men who sensed its dignity. No wonder the good missionaries loved these people as their very own. I could not help contrasting the order and decency and sanity of the Mission and its churches, hospitals, schools and farms with the miseries of witchcraft, fetishism and cannibalism and with the unspeakable abominations that used to be practised in this part of the world when a great chief died and hundreds of people were sent with him into the grave. Even now perhaps this Eden is not without its serpent. Some day jealous ambition may dethrone the benign rule of the French government and of the missionary, a republic or a soviet may arise and the sordid history of Liberia may be reenacted. But at present the terrors of barbarism have been suppressed, and the corrosive evils of civilization have not yet devastated the people; peace reigns, the happy children play jackstraws, mother toils patiently in the garden and father lolls in the sun. What next?

After we had purchased supplies at Yaoundé we set out for a village called Vimeli (Mbalmayo) about fifty miles south of Yaoundé, where gorillas had recently been reported.

It was early in the dry season and therefore the best time for the repair of the roads. Consequently, in many of the villages that we passed perhaps thirty or more people, mostly women and children, were engaged either in bringing small baskets of earth and gravel to throw down on the road or in clearing the ditches. As we rolled along the well-made roads bordered with oil palms, the folks working there proved hardly less responsive to a smile and a wave of the hand than the people of the Congo. Our quiet-voiced and meek-mannered cook Zé had brought in his hands his prized possession, a large mirror in a gilt frame. He was sitting on the baggage behind me and once in a while he would hold up the mirror rather shyly so that the women and children on the road could see their reflections in it. This never failed to bring smiles and a buzz of

Photograph by H. C. Raven

MENDING THE ROAD.

approval. Several times we passed chiefs who were out inspecting the work of their people on the roads. One of them was attired in a complete English riding habit and sat astride a very smart-looking horse; but his attendant was holding the bridle. Such a display of superiority in Africa makes everybody feel better; the owner's breast swells with pride and the people feel that a king has spoken to them. From the presence of the chiefs and of a policeman now and then we suspected that the people were not at work on the roads through any large-minded interest in the common weal but simply to free themselves from imprisonment for non-payment of taxes.

After a morning's ride through a more or less forested country we arrived at Vimeli and were most kindly received by M. Guillot, the *Chef de Poste*, who courteously invited us to share his residence with him. His house, or group of houses, was set in the midst of a large open plaza covered evenly with fine gravel. He gave us an immense high-ceilinged room, where we set up our cots and lived very comfortably. The square house was supported by a single high umbrella-tree in the middle, with wooden posts at the corners. No nails were used, the parts being bound together with twisted strands from the oil-palm leaves. The walls consisted of a system of interlaced uprights and horizontals like the ordinary native houses and for which the oil-palm likewise furnished the materials. The roof was covered with many layers of the immense folded-up leaves of the oil-palm and was practically rain-proof except at one small spot.

While lying in bed and looking up at the rafters of this house I realized that the native builders must have employed at best only the simplest methods of measurement and calculations. Dr. James Chapin informs me that during his long stay among the Mangbetou and other native tribes of the Congo he and Mr. Herbert Lang took considerable pains to find out how the natives made measurements in planning their houses. He said that they would take a stick of convenient length and lay off the distance so

many times along each side of a parallelogram, but that they had no standard stick for measuring, and his own measurements showed that they did not build the walls strictly at right angles to each other, although in constructing a circular house they knew how to describe a circle with a post for a center and a piece of fiber as a radius. In short, native Negro architecture and indeed their entire culture seems to be based on empirical methods rather than on precise measurements and calculations. Anyhow, our house at Vimeli was just as cool and comfortable as one could reasonably desire.

M. Guillot was a delightful companion and we learned from him much that was of value and interest about the natives and the natural history of the region. As *Chef de Poste* he acted as chief magistrate, and his court was crowded with people accused of minor offenses or seeking divorces or redress. Many difficulties arose from the inflexible opposition of both Catholic and Protestant Missions to bigamy and polygamy. When a man became a convert he had to give up all but one wife; but what was to become of the other wife or wives? We learned elsewhere that sometimes the cast-off wife would work in the fields for the Mission, but that her ex-husband would regularly call and take away her wages, apparently to repay him for the money he had invested in buying her from her parents. We heard also that some natives tried to be both Christians and polygamists at the same time. One can imagine that to the native man the chance to escape hell-fire and attain eternal bliss must at first seem well worth the price of a wife or two, even though each wife represents a big investment in cows or other goods and chattels; but practical difficulties arise when he has to decide which wife to part with. And probably the wives themselves are not altogether silent while the decision is being made. Thus one can also understand why the French Government is said to discourage the

Photograph by H. C. Raven

RESIDENCE OF THE *CHEF DE POSTE*, VIMELI.

From a motion picture by J. H. McGregor

DRIVER ANTS.

divorcing of second wives, and no doubt many quarrels, lawsuits and acts of violence must result from the turning out of helpless women from their own households.

At M. Guillot's I met two gentlemen who were connected with the French medical campaign against the sleeping sickness. From them, as well as from official reports I learned that in recent years many villages had been almost wiped out by this disease, but that, after the sterilization of the dead and immunization of the living by the traveling clinics, the mortality in a given district in the following year was greatly reduced. In some districts the organisms responsible for the disease had even been eradicated so that the tsetse flies were no longer infected and were consequently harmless.

The main square of Mbalmayo (the name of the town on the railroad, Vimeli being, as it were, a suburb of the town) offered a lively scene on market days, when rival shops employed barkers to yell at the natives, trying to persuade them that "our shop pays you the highest prices and sells the best goods at the lowest prices." But the natives, who had bombarded each other with verbal uproar all their lives, did not appear to be much influenced by the high-pressure selling agents. Here again no tongue or pen or camera could adequately convey the diversity and the comicality of these black folk.

The railroad at Mbalmayo was literally of pygmy size, with toy engines puffing about and blowing shrill little whistles. Down by the river the camions came to transfer great sacks of produce to tenders on the river. Here a ferry, comprising several large canoes, carried passengers across, while another ferry for autos was provided a little way up the river.

Two big canoes at this place were equipped as house-boats. On one of them a very large powerful young woman of the big forest-Negro type was preparing food; several of the men on shore seemed to belong to the same big race.

The smooth river gave back most attractive reflections of the opposite bank, and as one approached the other side in a canoe he saw an elaborate drapery of

long vines with the sun streaming down through the very high trees. The forest, although now ruined by the natives, except along the river bank, had evidently been of the general Congo type and doubtless had once harbored many chimpanzees and gorillas.

From a motion picture by J. H. McGregor
ALFRED.

During my walks around Vimeli I noticed that the very numerous umbrella-trees, in which the leaves are of the compound pinnate type, had grown up from a small bush in which one can trace a series of leaves of progressively complex form, beginning at the bottom with a more or less heart-shaped leaf with two projections, and passing through leaves with serrate margins to the greatly subdivided leaf of the sapling and fully grown tree.

One afternoon I heard music issuing from a drum and a xylophone in rapid march time, thus:

POM, pom, pom, pom;
POM, pom, pom, pom;
Pómpernickle,
Pómpernickle,
POM, POM.

On one of my walks I came across two great streams of driver ants, which were transferring their pupae across and

From a motion picture by J. H. McGregor

ALFRED AT PLAY.

under the railroad track. They had excavated a deep groove, which was in some places almost a tunnel, extending down a steep embankment across the hard clay ditch and path, under the ballast of the track, across the clay path on the other side, into the thick jungle. They had tried to cross the track over the rails, but possibly after some disastrous experience with a train had abandoned this path and gone through the ballast under the rails. Untold thousands of workers streamed in one direction, carrying the pupae in their jaws, suspended beneath their bodies. Both sides of the tunnel were guarded

From a motion picture by J. H. McGregor

JACQUELOT.

by aggressive soldiers with huge mandibles. These stood in hundreds, rearing up on their hind legs, with their jaws in the air. At several places the soldiers were massed in a living lattice-work above the open groove. When I crept up with extreme caution the warriors became only vaguely uneasy and did not know which way to rush toward the foe. Hence, being well guarded with heavy shoes and puttees I was able to flick off the few that chanced to find their way above the soles of my shoes. When I blew down on the mass the pandemonium among the soldiers was intense, as they rushed out in all directions seeking the offender; but the workers streamed on with their burdens. A grasshopper that I dropped into the middle of the pathway was hustled out of the way in a few minutes.

After I had had a good look at the ant army, I hurried home to tell McGregor, who had been seeking for just such an opportunity to get motion pictures. We immediately got the apparatus together, and he succeeded in getting many close-up views with a strong lens. McGregor went in shorts with bands of cotton around his legs. He was so intent upon getting good pictures that he allowed several of the soldier ants to get past his defences. Being an ardent entomologist, however, he allowed a few to bury their big mandibles in his skin; then he merely picked them off and would have preserved them if it had been practicable. Twenty-four hours later we went again to get more pictures and the procession was still going; but on the third day it had vanished.

Near the market-place at Mbalmayo there was a Greek merchant who owned a young captive gorilla, the liveliest specimen of his kind we had ever seen. On market days "Alfred," as he was called, stayed in front of the shop, romping with a little boy or held in the arms of one of the employees. The natives

From a motion picture by J. H. McGregor
JACQUELOT AND KITTEN.

coming to town with their produce were much amused by his antics, in which he reminded one of a chimpanzee rather than a gorilla. Alfred was most dexterous in hanging on to the post with one hand and two legs while holding a can of milk in his other hand. In drinking from the can, however, he was not particular about how much milk he spilled on his jumpers. If excited or especially interested in anything, he would rapidly beat his chest with his hands after the manner of adult gorillas.

From a motion picture by J. H. McGregor
MONGOOSE GETS NONE.

From a motion picture by J. H. McGregor
HAND OVER HAND.

M. Guillot also owned a baby female gorilla about eighteen months old and a number of other pets, including a parrot and a mongoose. The little gorilla was in excellent health and had the freedom of the house and environs. Most of the time she would sit quietly on the ground with her legs bent and her hands free to handle things—including the kitten. She was very deliberate but also very expert and adroit in all her movements. For instance, if she were eating a cracker and the mongoose came up and tried to snatch it, she would simultaneously turn her head away and push him away with one elbow, so that he had to make three or four sudden dashes before he could snatch even a piece of the cracker. In going after a bunch of bananas suspended from a horizontal support of the roof, she would climb up the vertical post by clasping it with hands and feet much as a native would climb a tree; then she would crawl along the under side of the horizontal beam, also grasping it with hands and feet. At such times the stresses on all the digits and especially on the thumb and great toe must have been exceptionally great.

From a motion picture by J. H. McGregor
REACHING FOR THE PRIZE.

Sometimes she would swing over to the vertical wire and then down to the bunch of bananas, holding on by one hand to the horizontal above and hugging the bunch of bananas with her body, legs and one hand. She would break off a banana with the free hand and hold it up to her mouth, then begin to strip the skin from the fruit. If she got tired holding on by one arm above her head, she would reach up with the other arm and release the tired one. When eating sugar-cane she held it by one hand and made very uncouth motions with her lips, almost like a human child.

She used her hands to handle things with and her feet to cling with, and it was evident that in this young gorilla the differentiation of function between the hand and the foot, which culminates in the human stage, is already under way, in spite of the fact that when walking on the ground the fore part of the body is supported by the knuckles of the

hand. So too in the young gorillas now living in New York, Philadelphia and Washington, any one may see that the hands, in spite of their present use in locomotion, are also used as true hands and that their feet, at least normally, are used not for the delicate manipulations of objects but merely to grasp with or for support in walking.

After a week of intensive but unsuccessful hunting in the country centering around Vimeli, Raven found that although gorillas had frequently been killed in that neighborhood they were not sufficiently in evidence there at that time to warrant further expenditure of time; so he decided to go back again to Yaoundé. Accordingly, after three days' delay, due to the failure of a certain camion to reach us on the day agreed upon, we took leave of our good friend and host, M. Guillot, loaded our equipment, our boys and ourselves on a camion and left Vimeli.

We carried also another passenger, the little gorilla, which McGregor had purchased from M. Guillot. She screamed terribly when shut in a large box behind wooden slats, but was somewhat comforted when McGregor sat near her and handed her bananas and oranges during the trip to Yaoundé.

On returning to the Mission at Yaoundé McGregor secured some excellent motion pictures of two young gorillas owned by Mr. Johnston. The larger one, "Bushman," was about three years old and in vigorous health. The small one, still a baby, was also in excellent health but less rough and aggressive than Bushman. Both would rush after their black nurse and, grasping his legs, would ride along on his feet as he moved thus handicapped. This clutching habit seems

From a motion picture by J. H. McGregor

EATING SUGAR-CANE.

From a motion picture by J. H. McGregor

STUDY IN HANDS AND FEET.

to be congenital in both young gorillas and chimpanzees and may be of value in preventing them from getting separated from their mothers or nurses.

During our several visits to the American Mission at Yaoundé McGregor took a lot of other motion pictures of the little gorillas, Bushman and the baby, together with our own little gorilla. It was very amusing to watch the behavior of these three small gorilla children when playing together. All three seemed to recognize their own kin and betrayed no fear of each other. Bushman, being the oldest, largest and most aggressive, would sometimes grab our little one by the hind leg and start to drag her around; she would push him away with her elbows and try to bite him. When she went under a bench he would follow and be very rude and rough. She would retreat and sit down in the sunshine, and soon his easily diverted mind would be on the trail of another idea and he would try to push himself through a big hole in the wall. In running about the young gorillas already swung their long straight forearms back and forth and stepped outside of their right hands with their left hind feet, after the manner of adult gorillas.

When the time came to leave we went down to the shops to purchase boxes and wire netting with which to make a cage. Raven made a fine one, light and strong, with nice straw on the bottom, but our little gorilla screamed like a baby when she was placed in it and exhausted herself in vain efforts to push through the netting.

McGregor and I then made ready to return home. We all hated to break up our pleasant fellowship in the field and we should not have left Raven if we could have substantially furthered the main business of getting gorillas or have been really useful to him in his field work. But he felt very confident that

by taking a camion farther into the interior and away from the big towns he would be able to get his two gorillas in a short time and to return home soon after we did. Moreover, he intended to make his headquarters at the medical mission at Dja-posten, near the Gaboon border, where gorillas were reported to be numerous and where he would be in close touch with our friends, Mr. Harris and other American missionaries.

A camion was solemnly promised for five o'clock next morning so that we could catch the train for Douala, leaving at 6:20 A. M. But five o'clock and even five-forty came and still no camion, and we and our baggage were over a mile from the station. Also if we missed this train we would inevitably miss the boat sailing from Douala on December nineteenth. In desperation we got our own boys and as many others as we could commandeer to put our pieces of baggage on their heads and start on the trek to the station. Our promised camion never appeared, but on passing through the village we heard another camion just being started on its way. We rushed up, told the driver our predicament and in a few moments were rolling down the long hill, sounding our horn to part the leisurely gangs of pedestrians. We arrived at the station in the nick of time, and the French stationmaster enjoyed screaming at the poor black ticket agent, who was patiently trying to calculate the tariff on our extra-weight baggage and to compute the other items which make their railroad tickets look like hotel bills.

As the train pulled out from Yaoundé I could not help feeling uneasy and even guilty at leaving Raven alone, but in a lifetime of exploration being "on his own" was his normal state, and Africa had been kind to us so often that none of us could have anticipated what was to happen. Meanwhile our poor little gorilla was screaming in the baggage car with a peculiarly disturbing and baby-like cry and would not be comforted by oranges, bananas or sugar-cane. At every station her screams rang out and stopped only when we put our fingers through the wire netting for her to clutch tightly. Our hearts sank as we foresaw the difficulties of the long voyage home, but it was too late to retrace our steps and all we could do was to visit and try to quiet our little ward at every stop.

All that day as we passed through the

From a motion picture by J. H. McGregor

LET ME ALONE.

From a motion picture by J. H. McGregor
"BUSHMAN" RUNNING.

Congo forests we gazed intently at it, realizing that this was our last chance to do so, at least on the present expedition. Again I regretted my lack of botanical knowledge, which might have given me some slight clue to this grand, chaotic battle of competing organisms. For the first time in my life I became aware of the very elementary fact that the height of any straight tree trunk must be an expression of the differences between two opposite forces continued over a long period of time: first, the universal downward pull of gravitation, and secondly, the upward thrust of an evenly balanced circle of live tissue growing up toward the light. But exactly how was the upward growth-pressure produced? Why did not the sap leak out through the roots, where the water was taken in? In other words, what held the column of water in place against gravitation? And why did the centrifugal or lateral pressure, which gave rise to buds and branches, produce such widely different results in different kinds of trees? I was so much interested in these queries that I forgot to feel ashamed that I had to go to Africa to become aware of their existence.

We arrived at Douala that evening and passed a busy following day doing some necessary shopping and securing a certificate of immunity from the organism of sleeping sickness, without which we could not purchase our steamer tickets. At the laboratory where we were examined a French doctor took our records, while a black assistant skillfully extracted a drop of blood from our fingers and prepared a smear for microscopic examination. From an official report on the subject I learned that before the traveling hospitals are sent out to fight the sleeping sickness the black assistants are taught to be skilful technicians, that they learn to make excellent microscopic preparations and can be trusted to make faithful and accurate reports as to the significant facts revealed by the microscope. After securing a clean bill of health we purchased our tickets and repacked all our baggage ready for our departure at six the following morning.

That evening as we sat at dinner in the hotel a splendid big rhinoceros beetle came flying into the dining-room. Its flight was very clumsy, and its heavy black body and reddish wings gave it the appearance of a flying toy. I made an ineffectual attempt to catch it, but the waiter knocked it down and I then caught it in my handkerchief. Seizing it by the back I marvelled at its strength and at the curious way in which the tip of its great backwardly curved horn could be opposed to a crotch-like branch that grew out from its neck-plate. But as we had no means of preserving it, I set it free.

One of the idiosyncrasies of many African hotels is that, as the managers and waiters have to stay up till very late serving refreshments to customers, they are mostly dead to the world early in the morning, so that the guest departing on the only outgoing train or boat of the day, which usually leaves around six in the morning, can get no breakfast and is

lucky if he can bribe some boy to wake him in time. On the morning of the day of our leaving Africa I awoke at 4:00 A. M. and, being afraid to go to sleep again, got up and dressed. At 4:30 A. M., an hour and a half before we needed to leave the hotel, a black boy came to wake me. So I passed the time in looking out the window, watching the brilliant stars, the tree frogs and the fruit bats. Shortly before six McGregor and I (having sent most of our baggage down to the wharf the afternoon before) took a few boys from the hotel to carry our remaining baggage and walked down a few blocks to go on board the tender, which took us down the long estuary to meet the *Asie*. Meanwhile our little gorilla had been very content, sitting on the lap of a black boy whom we hired to look after her day and night.

So we went up on board the big steamship and thus our share of the African expedition was practically finished. A few days later, after leaving Dakkar, we veered away from the African coast. Here at Cape Verde the continent was slowly giving back before a furious attack of the ocean. Through our field glasses we could see immense waves boiling against the rocky cliffs and rushing through narrow openings in the rock. In some places the waves had worked their way into the cliff from opposite sides, first tunnelling it and finally cutting through the arch above the tunnel, so that separate islands now stood as outposts of the main mass. As this grand scene faded from view a troop of friendly dolphins came out to speed us on our way, and that was the last we saw of Africa.

From a motion picture by J. H. McGregor
GORILLA BABY RUNNING.

(*The next two sections, entitled respectively, "Hunting Gorillas in West Africa" and "Men, Gorillas and Sleeping Sickness," by H. C. Raven, will conclude the series.*)

EARLY PHOTOGRAPHY IN THE MEDICAL SCIENCES

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PHOTOGRAPHY is of particular value to the scientist because it has two characteristics which no other method of reproduction possesses. It produces an accurate and impartial record of the field upon which its lens is trained, and it permits seizing and rendering permanent the more-or-less evanescent changes that ordinarily occur too rapidly for complete study. These valuable properties of the photographic camera have such wide application that inspired hands from all fields of science have worked toward the perfection of the chemistry and physics of this scientific tool. In the medical sciences there has been need of special photography for particular purposes, and ingenious devices for photographing almost inaccessible parts of the body have been developed. To-day specialized photographic apparatus for medical purposes has reached a high degree of perfection, and it is possible to photograph such fields as the interior of the stomach or the retina of the eye with such good results that the photograph secured is perfect enough to form the basis of an accurate study or diagnosis.

This perfection has not come immediately, but has been the result of much work and experimentation. The development of photography as applied to medical sciences before 1900 is especially interesting because in that period of its development all the fundamental methods were invented, and although there have been many improvements since, both in cameras and emulsions, the ingenious devices invented by these early workers have been the basis for the successful medical photography of to-day.

Photography has served medical science in two ways. First, it has been a research tool, and as such it has been used to make records for detailed studies. In the clinic, for example, visual examinations can not always be accurate and complete, and so photography has been employed for making permanent records from which careful studies and comparisons of a condition at different times can be made. It has also proved valuable to the physiologist, who used it with great success as a means of recording physiological function with the photographic kymograph. The second use of photography is in the illustration of original scientific findings and in teaching. Here it is used to supplement or replace verbal descriptions. The availability of photography for this purpose depended, of course, upon the invention of inexpensive and efficient engraving methods in order to achieve quantity reproduction. These methods lagged behind the development of photography, and thus, as new photographic procedures became available, it was not always possible to take full advantage of them. Photolithographic methods found some use in the reproduction of photographs, but it was not until the invention of the half-tone engraving method in 1882, by George Meisenbach, that a really efficient and inexpensive means of quantity production was available.

There were, however, some publications before the invention of photoengraving which contained original photographic prints. In 1877 Bourneville[1]

[1] The first of these three volumes, entitled "Iconographie Photographique de la Salpêtrière," was published in 1877. Two subsequent volumes were published in 1878 and in 1879.

published an excellent volume containing over 50 prints made directly from negatives taken by Paul Regnard of mental patients in the hospital of Salpêtrière. The results were highly satisfactory, and some of the photographs reproduced in this book serve their purpose beautifully. In two subsequent volumes by the same authors, lithographic methods were used to reproduce the photographs. By means of these photographs and the detailed case histories contained in these volumes it was possible for the student or practitioner to learn a great deal. Some of the early atlases of pathology and skin diseases were also illustrated with photographs and serve to show what could be done with photography along this line. The wide-spread use of treatises of this nature was hampered, however, more by the restrictions of the manifolding processes than by the photographic difficulties of the time.

Photographic Kymographs

The inherent characteristic of photography—its ability to stop motion, and thus seize some segment of time to hold it fixed and available for a leisurely, accurate study—has been used with the greatest effectiveness in the analytical studies of motion. Jules Marey in 1885 used photography for the analysis of movements in man, animals and birds. For part of his work he made a series of exposures on the same plate, which resulted in a composite photograph showing successive positions of an individual performing such commonplace acts as walking, running or jumping. By taking a series of pictures in rapid succession he obtained a similar result, and these experiments, with the work of Muybridge, the Lumiere brothers and others, formed the foundation of the modern motion pictures.

It is frequently of great value for the physiologist to be able to record in some permanent fashion the physiological changes that take place so quickly that they can not be studied directly with any degree of accuracy. For example, a single heart beat takes place in less than a second and can not possibly be studied directly. This was partially solved by Chauveau and Marey in 1863, the heart writing a record of its contraction through a system of levers upon a smoked paper. This was a great contribution to

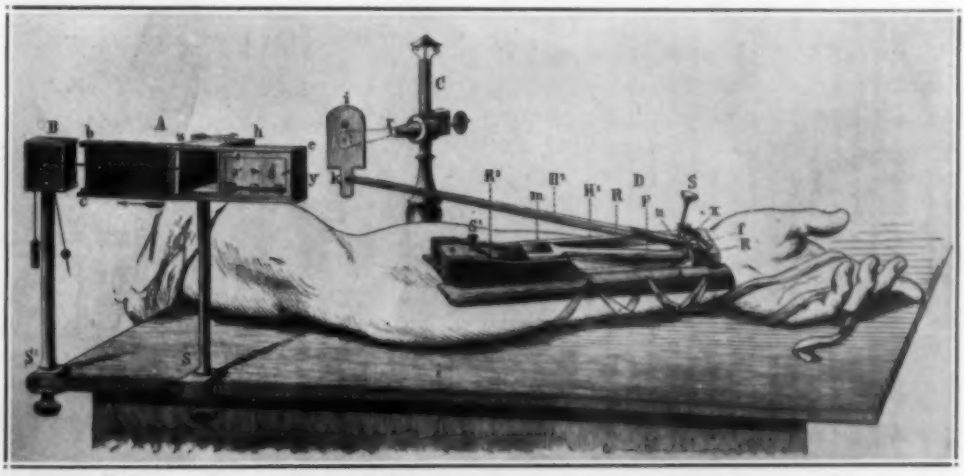

FIG. 1. THE PHOTOGRAPHIC METHOD OF RECORDING THE PULSE WAVE DEVELOPED BY STEIN FROM MAREY'S SPHYGMOGRAPH IN 1885.

physiology because it gave experimenters a means of accurately studying the function of organs. But it had the disadvantage of losing many of the delicate features of physiological function in the comparative crudity of the levers and mechanical contrivances which translated the function into a graphic record upon the smoked paper. To overcome this difficulty photography has been used with great effectiveness. The plate in a cassette, or photographic paper on a kymograph drum, is moved rapidly behind a slit in a light-tight box, and the record made with the aid of light. Fig. 1 shows the arrangement used in 1885 by Stein for recording the pulse wave photographically. This arrangement did not differ markedly from Marey's sphygmograph, in which the pulse wave was recorded on smoked paper. The record was made with a beam of light passing through the perforation in the screen to the photographic plate as it was drawn past the slit. This photographic method of recording did not have any very great advantage over the usual smoked paper method. It eliminated the friction of the writing point against the smoked paper, but did not overcome the greatest difficulty, which lies in the mechanical losses of the lever system.

The value of the photographic method of recording lies in another arrangement by which most mechanical losses are practically eliminated. This method was foreshadowed by Czermak in 1863, when he demonstrated the pulse in his lecture room by allowing the sun rays from a heliostat to fall upon a thin plane mirror lying on an artery. The mirror reflected the rays of light upon a screen, and thus the pulsations, greatly magnified, were made visible. He suggested the use of a moving photographic plate for making permanent graphic records of the movements.

Such an arrangement has been used by Wiggers in his work on endocardial pressures. In his optical manometer an arrangement was used which transmitted the endocardial pressures to a diaphragm which actuated a small mirror. A beam of light falling upon this mirror and reflected to a moving film made a graphic record of the changes in pressure. This method was so far superior to the mechanical methods that had been used previously that for the first time the conditions of pressure inside the heart and large blood vessels were understood.

Variations in pressure can also be recorded by another photographic method. Tissander in 1874 described in his book on photography[2] a method of recording temperature or barometric pressure by allowing the shadow of the mercury column to fall upon a photographic paper moving behind it in a light-tight box. This method is the most direct way of measuring variations in pressure and has been used widely for types of work in which delicate changes in pressure must be recorded, such as measuring intra-ocular or intra-cranial pressure or for recording changes in volume in plethysmographic work. The principal loss from the inertia of the fluid is small, and since there are no other losses even the most delicate fluctuations leave their mark upon the photographic film or paper.

The general arrangement used for making recordings of this sort was to enclose the drum carrying the photographic paper or film in a light-tight box, on one side of which was a slit under which the film or paper passed. A glass tube of uniform bore was placed over the slit, and if the liquid within the tube was opaque, like mercury, a record resulted in which the lower half of the paper or film was unexposed, the light from the exterior being interrupted by the mercury. If water was used, the rays of light were brought to a sharp focus by

[2] "Les Merveilles de la Photography," by Gaston Tissander, Paris, 1874.

the water, and this part of the paper or film was much darker than the portion covered by the tube containing air which diffused the light. In some cases a drop of an immiscible liquid, containing a dye which interrupted the light, was made to float on top of the water column, thus more sharply delineating the two areas.

The study of action currents has been accomplished almost entirely with the aid of photography, which was used in early investigations to record the fluctuations of the mercury meniscus of the capillary electrometer. As early as 1878 Marey described methods of photographing the fluctuations of the mercury meniscus in the Lippmann capillary electrometer, and in 1887 Waller studied the action currents of the human heart by strapping zinc electrodes, wrapped in chamois and soaked in brine, to the chest and back. He photographed the fluctuations of the mercury meniscus of the electrometer as it responded to the minute electromotive changes in the heart by projecting the image onto a moving photographic plate.

These methods were used by Kreis in 1895 and by Einthoven in 1900 in their pioneer work on electrocardiography. Einthoven soon abandoned the capillary electrometer for a modification of the D'Arsonval type of galvanometer which he invented and called the string galvanometer. In this instrument the movements of a fine platinum wire or a silvered quartz thread in a powerful magnetic field indicated the action currents of the heart or other muscle. These movements are also recorded by photography. The projected shadow of the string is allowed to fall at right angles to a slit under which moves the film or paper, and the fluctuations of the string are recorded as a white line. In some of the more recent electrocardiographs the action currents are amplified and then led to a D'Arsonval type of galvanometer. Light is reflected to the moving film from a tiny mirror mounted on the coil.

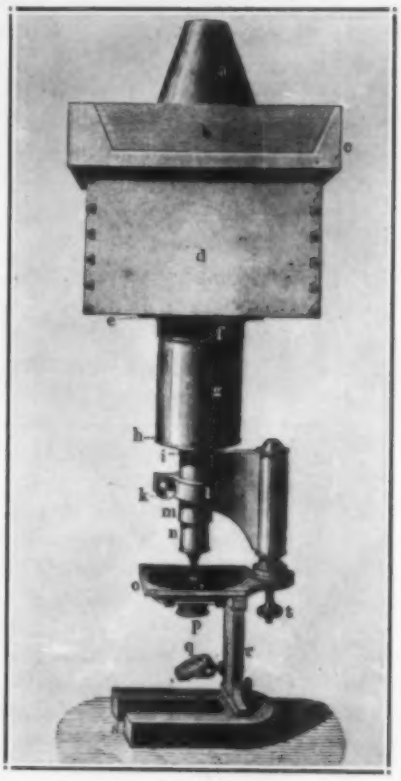

FIG. 2. A MICROSCOPE WITH ATTACHMENT FOR DAGUERREOTYPE PHOTOGRAPHY. THIS IS THE ARRANGEMENT USED BY VON GERLACH IN 1860.

PHOTOMICROGRAPHY

The application of photography to microscopy was one of the first scientific uses of photography. This was probably because the microscope had already reached a stage of comparative perfection by the early nineteenth century at the time photography was born, and it was a simple step to combine the two. This was facilitated by the camera lucida attachments of the microscope, which projected an image of the field onto a sheet of paper where it could be traced.

Even before the perfection of the daguerreotype and calotype processes, it

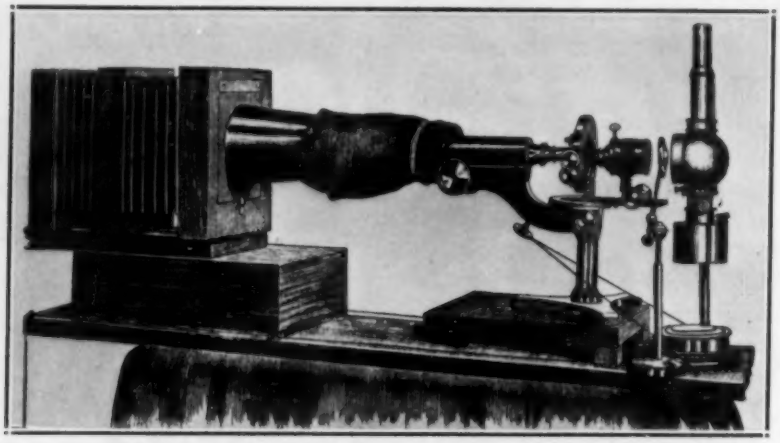

FIG. 3. WALMSEY'S PHOTOMICROGRAPHIC APPARATUS OF 1883.
IT IS TYPICAL OF THE TYPE USED DURING THIS PERIOD.

has been reported that Wedgewood and Davy applied their pioneer methods to microscopic photography; and in 1837 J. B. Reade made photographs of entomological specimens and sections of vegetable tissues with a solar microscope. He used paper coated with nitrate of silver and fixed the image with an infusion of galls. However, it was not until Daguerre and Talbot perfected their methods that photomicrography was really successful.

The actual arrangement of the camera and microscope for photomicrography was simple, and has not radically changed even to the present day. Improvements have come mainly through the perfection of photography and to better methods of illumination. The arrangement used by such early workers as Donné in France in 1840 consisted of a box suitably arranged to carry the daguerreotype plate, fitted over the end of the draw tube of a microscope. After the selection and focusing of the field was completed, the eyepiece of the microscope was removed and the image allowed to fall upon the sensitized plate. Illumination was usually by sunlight, although for lower magnifications gas or kerosene lamps were used. Donné in 1840 presented to L'Académie des Sciences a series of photomicrographs made on daguerreotype plates, and in 1845 published with Leon Foucault an atlas which contained engravings taken directly from daguerreotypes he had made. Fig. 2 shows one of the daguerreotype cameras arranged for microphotography.

Two problems confronted these early workers: first, the refinement of the photomicrographic apparatus and, second, the development of suitable illumination. Many modifications of the simple camera and microscope were used. Moitessier in 1866 used small plates which were placed over the draw tube of the microscope after removal of the eyepiece. The plates were held in a shallow box arranged with suitable shutters for exposing the plates. This shallow box was held in position over the microscope by a frame, and by means of a sliding arrangement the openings were successively brought into proper relations with the microscope. This arrangement was modified by Verick in 1885. His apparatus consisted of a long shallow box which fitted over the draw tube of the microscope after the removal of the eyepiece. In this shallow box were five

movable plate carriers which could be brought successively over the openings of the microscope tube. Another arrangement used by Benecke in 1869 consisted of a rotating disk which carried the plates and brought them successively over the opening of the microscope tube. In all these arrangements a small negative resulted and therefore these methods were particularly useful where weak illumination had to be used. There was also the advantage of convenience and portability, and of course a number of exposures could be made in rapid succession. The pictures produced were, however, too small to be of great practicability and better results were obtained with the larger instruments.

The large photomicrographic cameras agreed to a large extent in their general arrangement. The apparatus of Walmsey, Fig. 3, may be considered typical. His apparatus, described in 1883, consisted of a bellows camera which was connected to the draw tube of a microscope by means of a light-proof cloth. This prevented the vibration incidental to inserting the plate holder from disturbing the adjustment of the microscope. Light from a kerosene lamp was used for illumination. Excellent work was done during this period by Maddox in England and Cox in the United States, both of whom used arrangements essentially the same as Walmsey's.

At the end of the Civil War work was begun by the United States Medical Museum for the study of "minute anatomical changes characteristic of camp diseases, and of fever and diarrhoea."[3] As a result of this project over 1,400 microscopic slides of both normal and pathological structures were collected; and it was thought desirable to make these findings more widely available. Drawings of these slides were not regarded as ideal, and the far-seeing J. J. Woodward, who was in charge of the medical section of the museum, instituted efforts to reproduce this material photographically. First under Assistant Surgeon E. Curtis and later under J. J. Woodward himself, this pioneer work

[3] This undertaking is described in a rather rare publication of the Museum of the Surgeon-General, "Report on the Extent and Nature of the Materials Available for the Preparation of a Medical and Surgical History of the Rebellion," 1865.

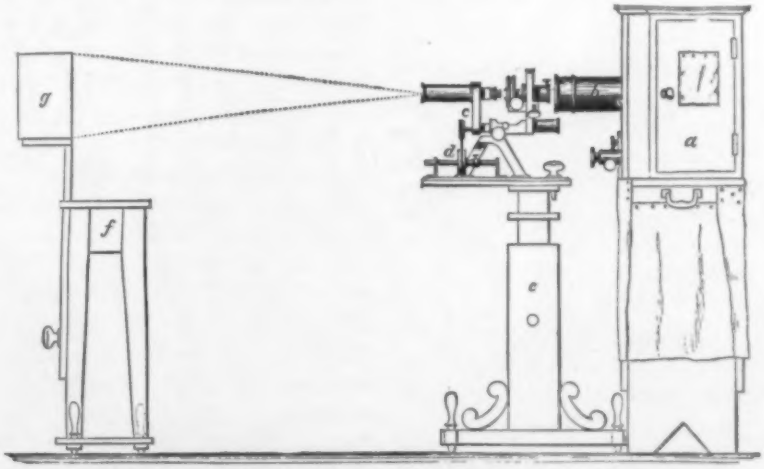

FIG. 4. PHOTOMICROGRAPHIC APPARATUS

USED BY WOODWARD AT THE MUSEUM OF THE SURGEON GENERAL IN 1870. IT WAS USED IN A DARK ROOM. THE ARC OR MAGNESIUM LIGHT WAS CONTAINED IN THE HOUSING "a," AND THE PLATE CARRIED IN THE HOLDER "g."

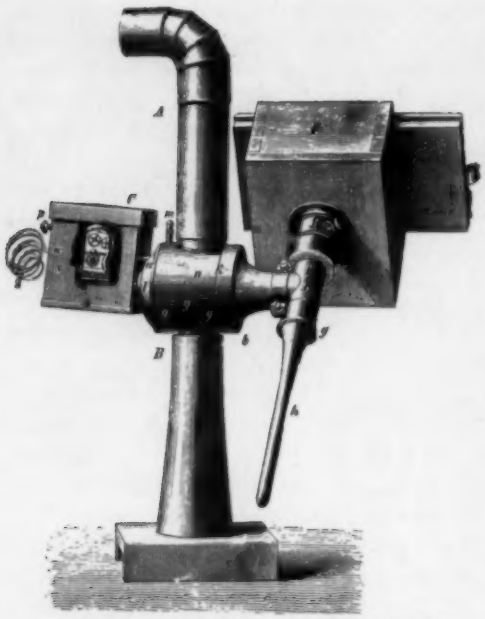

FIG. 5. REFLECTING ENDOSCOPE OF DESORMEAUX ADOPTED FOR PHOTOGRAPHY. A PERFORATED MIRROR SET INSIDE THE JUNCTION OF THE TWO TUBES AT "x" REFLECTED LIGHT FROM THE BURNING MAGNESIUM RIBBON INTO THE SOUND "h." THE CAMERA IS AT "F."

was developed. Sunlight was used for illumination and the apparatus was arranged so that the rays of the sun were directed by means of a heliostat onto a condensing lens which focused them on the plane mirror of a microscope. A cell of ammoniacal copper sulfate solution was used to absorb the heat rays. The tube of the microscope was thrust into a long camera box and the connection made light-tight with a black silk cloth. Collodion plates were used and exposures of 30 to 40 seconds were required. With this apparatus, magnifications of 7,000 diameters were attempted, but the greatest success was achieved with the lower powers.

It was hoped that these photographs could be manifolded for general circulation by photo-lithography, but at that time this process proved to be unequal to the task of reproducing the fine textures of the photographic negative, and hand engravings were finally made from the photographs.

In 1870, Woodward, dispensing with the camera as such and using a totally dark room, began experiments with artificial light. The light source, consisting either of an arc light or a magnesium light, was enclosed in a light-tight box, and the rays were allowed to fall upon the achromatic condenser of a microscope after they had passed through an ammoniacal copper sulfate solution and a condensing lens. This arrangement is shown in Fig. 4, which is taken from Woodward's original report to the surgeon general.[4] The microscope was focused with the aid of the eyepiece, which was then removed, allowing the image to fall on the plate. The plate was fastened to a support which could be moved about the room by means of castors. The pictures made with this arrangement were 5 inches in diameter and are still beautifully clear and sharp.

The artificial light employed by Woodward was somewhat of an innovation. The illumination previously employed was either sunlight for high magnification or the light of the gas or kerosene lamp for lower magnifications. C. F. Grehore of Boston had made some use of an arc light, as had Moitessier with his small camera, and the oxy-calcium light had been used by Dr. Wilson in 1867. Using the arrangement shown in Fig. 4, Woodward experimented with both of these light sources with excellent results. He lays claim to originality in the use of this kind of illumination in the following words: "I have no hesitation, therefore, in claiming for the Museum and for myself the credit of having demonstrated the serviceable character of these lights as sources of illumination for the preparation of negatives with high

[4] "Report to the Surgeon-General of the United States Army on the Magnesium and Electric Lights as Applied to Photo-micrography," by J. J. Woodward, 1870.

powers, and of having devised a simple method which brings their use within the reach of every microscopist."

Among the ingenious auxiliary devices for photomicrography was the means of taking stereoscopic photomicrographs. This could, of course, be done by photographing the images in the two tubes of a binocular microscope, but the same result could be obtained, as explained by Benecke, by slightly tilting the slide so that two photographs could be taken at slightly different angles. He used a tilting table which was attached to the stage of a microscope and he controlled the amount of inclination by the use of a wedge so that a matched pair of photographs would result. This was applied most successfully to opaque objects. Another device used in 1866 by Moitessier consisted of a cap which fitted over the objective of the microscope. This cap turned through an angle of 180 degrees and obscured opposite sides of the objective successively. Photomicrographs thus taken gave a stereoscopic effect when properly viewed.

The inherent lack of depth of focus in the microscope was at least partially overcome by Villanes, who made successive exposures of different planes of focus. He provided the knob of the micrometer adjustment of the microscope with an index pointer and circular scale. After noting the position of the pointer when the lowest and highest part of the object was in focus he made three or four exposures on the same plate, changing the index pointer to different positions on the scale between the two extremes of focus previously noted. The resulting negative is not as clear as one made with a single exposure, and this procedure has not enjoyed very extensive use. The problem of the small depth of focus in microscopic photography is inherent in the lens system of the microscope, and the most practical plan has been to focus on the most important part of the field.

By 1890, amateur photography had become wide-spread, and with the ubiquity of amateurs no field of photography was left unexplored. This enthusiasm is evidenced by the fact that in the *American Annual of Photography* for 1891 there are three articles dealing with photomicrography. Although much of the work done by these amateurs must have been as a hobby rather than a science, it must be admitted that they simplified photomicrography to its barest essentials. One of these articles describes an arrangement by which a box camera without any alteration whatsoever may be used for photomicrography by bringing its lens almost into contact with the eyepiece of a microscope. The two are joined by a metal ring, and with a kerosene lamp for illumination excellent photographs were taken with an exposure of 3½ to 10 minutes. Quite recently this arrangement was reported as something new.

In recent years there has been a revival of interest in photography with a microscope among amateurs. This has been due, in part, to new developments of photographic materials and the use of color filters with panchromatic emulsions. But another factor of probably

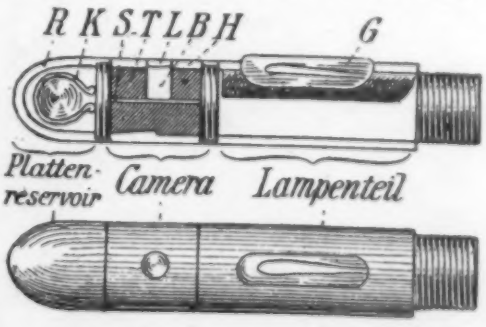

FIG. 6. GASTRIC CAMERA

DEVISED BY LANGE AND MELTZING IN 1898. IT WAS CARRIED INTO THE STOMACH ATTACHED TO A STOMACH TUBE. THE ROLL OF FILM IN THE CAVITY "K" WAS DRAWN PAST THE LENS "L" BY MEANS OF A CORD EXTENDING THROUGH THE STOMACH TUBE. AN ELECTRIC LIGHT "G" EXPOSED THE FILM.

FIG. 7. EARLY METHOD OF PHOTOGRAPHING THE LARYNX.

THE SUBJECT MANIPULATED THE LARYNGOLOGICAL MIRROR, OBSERVING ITS MOVEMENTS IN THE MIRROR "c." LIGHT FOR ILLUMINATION WAS FURNISHED BY THE PERFORATED MIRROR "C."

greater importance has been the interest of the modern artist in design. The artistic photographer has found that the microscopic world abounds in rich patterns and he has turned his camera to this new field for artistic inspiration.

PHOTOGRAPHIC ENDOSCOPY

Endoscopy, or the visual inspection of hollow organs, was first accomplished by the insertion of a suitable metal tube into the organ. Examination was made with the aid of light reflected through this tube by a mirror perforated for observation. Desormeaux, though not the first to make use of this principle, thoroughly studied the possibilities of such an arrangement for the visualization of the interior of the bladder. He began his experiments in 1852 and in 1855 had perfected his methods. A description of this instrument and the results of ten years' experience with it were published in 1865.

Desormeaux's endoscope consisted essentially of a sound which was suited to the organ to be examined, and of a mirror set obliquely at the outer opening. A beam of light was reflected by the mirror, passed through the tube and illuminated the structures within. Light from the burning of a mixture of alcohol and turpentine was used for illumination. It required but small modifications of this instrument to adopt it for photographic purposes. Fig. 5 shows Desormeaux's endoscope combined with a photographic camera.[5] With proper sounds this apparatus could be used to make photographs of the urethra, bladder and rectum. A modification depending upon the same general principle of observing or photographing the field through a perforated mirror was used by Brunton, who developed an otoscope, which was easily

[5] This figure is reproduced from "Das Licht im Dienste Wissenschaftlicher Forschung," by Sigmund Stein, published in 1885. Stein was very active himself in applying photography to the sciences and his book describes in a great detail the photography of his day in the service of science and contains many illustrations. Figs. 1, 2, 5, 7, 10 and 12 are from this book.

adapted for photography by the addition of a suitable camera.

Attempts were made to photograph the stomach by similar methods without success. Photographic gastroscopy was too great a problem for reflected light, and indeed even when illumination of the stomach cavity by means of an electric light carried into the stomach with the stomach tube made visual gastroscopy comparatively simple, practical photography was still extremely difficult. Visual gastroscopy was attempted with some success by Kussmaul in 1868, and Trouve in 1873, but it was not until Mickulicz in 1881 used a small electric bulb on the end of the gastroscope to illuminate the stomach that observation became really possible, and even then it was attended with practical difficulties. Photography of the image seen in the gastroscope was successfully achieved by Elsner, who in 1928 was able to photograph the image observed with the gastroscope, but the procedure was too complicated to be practical.

Successful photography of the interior of the stomach was finally accomplished, however, by the innovation of introducing the camera itself into the stomach. This arrangement seems to have been first used in 1898 by Lange and Meltzing, who took advantage of the then comparatively new flexible film. A small strip of this film a little more than 4 mm in width was rolled into a loose spiral and placed in the end of the apparatus in the small cavity at K in Fig. 6, which is a reproduction of an illustration from the article by these investigators. This film strip was drawn past the lens L through the slot S by means of a strong cord, which extended through the lumen of the tube to the outside. By pulling this cord a short distance after each exposure, successive negative images could be secured on the film strip. The exposure was made by turning on the light for one half to one second. A circular negative 4 mm in diameter was secured. This ingenious device was, however, limited in its success. The difficulty of orienting the camera made it too much like "shooting in the dark" for practical use.

This development was the forerunner of the gastrophotor, invented by Heilpern and Porges in 1930, in which 8 stereoscopic photographs covering the entire interior of the stomach are taken by means of pinhole cameras which eliminated the necessity of focusing. After uncovering the pinholes a single flash of intense light lasting for 1/120th of a second exposes the pictures. All portions of the stomach are photographed simultaneously, and the exact conditions of the interior of this organ can be determined. Although it lacks the advantage of showing natural colors, there is no doubt but that this recent achievement of photography will prove of the greatest diagnostic value.

Photography of the Larynx

Early attempts to photograph the larynx were made by Johann Czermak in 1860. He had improved and extensively used the laryngoscopical mirror which had been devised by Robert Liston and Garcia in about 1854. His photographic methods consisted essentially of photographing the image in the laryngological mirror. The subject manipulated the laryngological mirror observing its reflections of the larynx by means of a small plane mirror. Light was thrown into the pharynx by a concave mirror with a central opening similar to the present-day head mirror. An observer, by applying his eye to the opening in this mirror, could observe approximately the same image in the laryngeal mirror as the subject. Photography was accomplished by placing a camera behind the perforation of the head mirror in the same position as the eye. The kerosene lamp, which was not sufficiently bright for photography, was replaced by sun-

light. By this means Czermak was able to make fairly good photographs of the normal larynx. He was handicapped by the comparatively primitive state of photography, and of course, since autolaryngological methods were used, the application was distinctly limited. Minor improvements on the general method used by Czermak were made by Stein, whose arrangement is seen in Fig. 7, and the same methods were used by others, but without marked improvement over the results obtained by Czermak.

In 1884 Lenox Browne and Emil Bhenke used photographs to illustrate their book, "Voice, Song and Speech." They attached a mirror to the shutter of the camera and the subject watched his manipulation of the laryngeal mirror in this mirror. Upon his signal the operator tripped the shutter, and the exact image which he observed impinged itself upon the sensitive plate. By this simple arrangement, the parallax which was present in other methods was avoided. Light from a 10,000 candle power arc-light was used for illumination. This passed through a water chamber to reduce the heat, through two plano-convex lenses and was reflected by a plane mirror into the pharynx. A rapid rectilinear lens was used and an exposure of one fourth second was required.

FIG. 8. A PHOTOGRAPH OF THE LARYNX

TAKEN IN 1884. THE LARYNX IS SEEN REFLECTED BY THE LARYNGEAL MIRROR IN THE CENTER OF THE PICTURE.

One of the photographs taken in this manner appeared as the frontispiece of "Voice, Song and Speech" and is reproduced in Fig. 8. The actual image of the larynx is very small and the major portion of the plate is taken up with the out-of-focus image of the subject. In this photograph one can see how the picture was taken. The right hand is seen holding the mirror, and the forefinger of the left hand, which has just been lowered as a signal to trip the shutter, can just be made out. The small portion of the plate containing the image of the larynx was enlarged by copying for detailed study. Photographs reproduced in the book were used to show the position of the vocal cords during the production of different notes in singing.

These methods, while they reproduced the larynx, were subject to serious disadvantages. They could be used only by a subject who had skill enough to demonstrate his own larynx, and were thus restricted in their use to scientists or investigators, and could not be used with ordinary patients.

In 1882 Dr. T. R. French and Mr. G. B. Brainerd devised a method of taking pictures of the larynx which was both new and unique, and entirely supplanted the methods using the conventional camera. Dr. French was clinical professor of diseases of the throat and nose at the Long Island Hospital of Brooklyn. There he treated Mr. Brainerd, a civil engineer and amateur photographer, for a minor throat condition. Because of this situation, Mr. Brainerd became in-

terested in the problem of photographing the larynx and cooperated with Dr. French on the mechanical and photographic part of the problem. After a few experiments using the conventional type of camera, they discarded it in favor of a small hand camera which in appearance resembled some of the miniature cameras which are so popular today. They worked two years perfecting their apparatus and procedures and finally were able to take photographs wherever visual examination of the larynx could be made with the laryngeal mirror. In its perfected form the camera was $10\frac{1}{2}$ by $1\frac{1}{2}$ by $\frac{7}{8}$ inches, with an achromatic meniscus lens $\frac{1}{2}$ inch in diameter with a focal length of $1\frac{3}{8}$ inches, and was held in a tube in front of the camera. The shutter was of hard rubber and dropped by gravity across the field when the release, located conveniently in front of the camera, was tripped. To one side of the camera an arm carrying a slightly convex laryngeal mirror was firmly attached. The mirror was thus kept in rigid relation with the lens and plate of the camera. An arrangement was made whereby five pictures could be exposed with one loading of the camera.

The arrangement for using this instrument is seen in Fig. 9, which is a reproduction of cut in one of the original articles by Dr. French. Sunlight used for the illumination passed through a system of condensing lenses and was reflected by a head mirror into the pharynx. The laryngeal mirror attached to the camera was manipulated by moving the entire camera, which was held in the operator's right hand while he observed the image through the opening in the head mirror. At the proper moment the shutter was tripped and the image secured on the plate was almost the same as that seen by the eye. The small amount of parallax could be compensated for after some experience. With

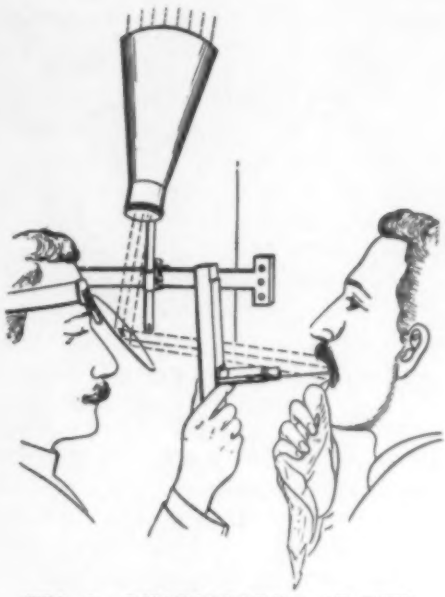

FIG. 9. PHOTOGRAPHY OF THE LARYNX

BY MEANS OF A SMALL HAND CAMERA DEVELOPED BY FRENCH AND BRAINERD IN 1882. SUNLIGHT, AFTER PASSING THROUGH THE CONDENSING LENSES, WAS REFLECTED INTO THE PHARYNX BY THE HEAD MIRROR.

this apparatus and with the "instantaneous exposures" of which it was capable, studies were made of the normal larynx during phonation and of the larynx in numerous pathological conditions. Without a doubt, this apparatus was the first method by which the larynx could be photographed in such a way as to yield results from which scientific studies could be made.

Once it had been pointed out that large plates were unnecessary and that the usual bulky camera was a handicap, rapid strides were made. Sigmund Stein adapted to the photographic purposes the illuminated laryngoscopical mirror developed by Nitze and Leiter and patented in 1878. This mirror carried a small electric bulb cooled by a suitable water system at the apex of the laryngological mirror. This was combined with a small camera essentially

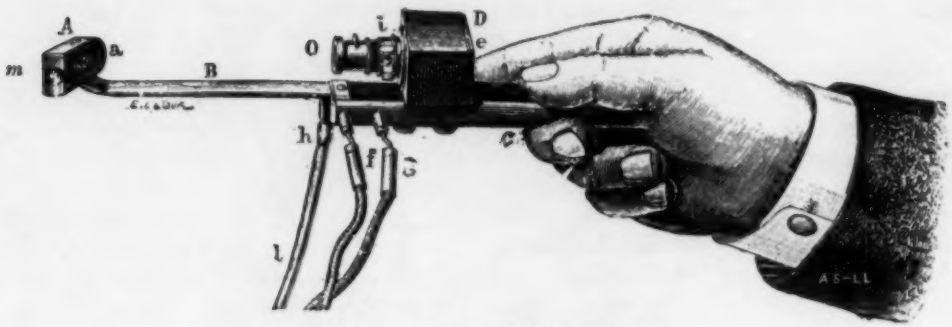

FIG. 10. LARYNGEAL CAMERA.

STEIN'S IMPROVEMENT OF FRENCH AND BRAINERD'S CAMERA. AN ELECTRIC BULB COOLED BY CIRCULATING WATER FURNISHED ILLUMINATION.

similar to that of French and Brainerd, except that an electrically operated shutter was used. The small electric bulb held close to the larynx was more efficient than the sunlight and made the investigator independent of the weather. Stein's camera is shown in Fig. 10.

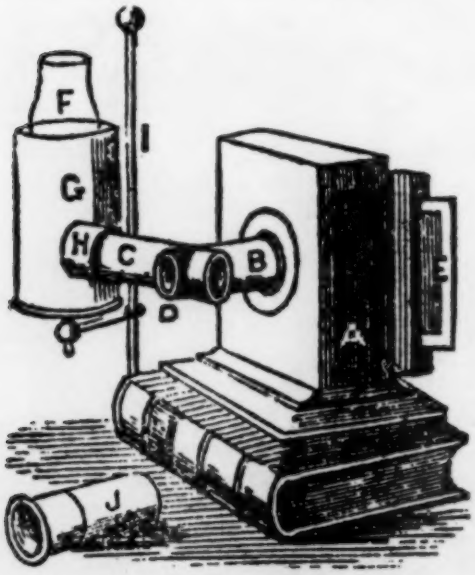

FIG. 11. ROSEBURGH'S APPARATUS

FOR PHOTOGRAPHING THE FUNDUS OCULI OF THE EYE IN 1864. THE EYE WAS PLACED AT "D," LIGHT FROM THE LAMP "G" WAS REFLECTED INTO THE EYE BY A GLASS PLATE SET IN THE JUNCTURE OF THE TWO TUBES. A LENS WAS PLACED IN THE TUBE "B" AND THE PLATE-HOLDER IS AT "E."

Thus photography of the larynx became practical, and the most recent improvement has been an instrument devised by Otto Ehrentheil and Franz Black, in 1932, in which a tiny pinhole camera with an electric light is carried back into the pharynx to make a direct photograph of the larynx.

PHOTOGRAPHY OF THE FUNDUS OCULI

As early as 1862 attempts to photograph the retina were made by Noyes of New York. He was unsuccessful, however, and his negatives only imperfectly represented the retina. He described his methods before the Section d'Ophthalmologie du Congres Copenhague in 1864. Sinclair of Toronto, Canada, also made some attempts, but both of these investigators encountered great difficulty, due to reflections from the cornea and the movements of the eyeball during the long time required for exposure.

The first successful photography of the fundus oculi was accomplished by Roseburgh in 1864. A reproduction of an illustration of his camera which appears in his original report is shown in Fig. 11. A plate of glass set at the junction of the two tubes served to reflect the light from an external source into the eye and also allowed the image of the retina to pass to the sensitive plate. The wet collodion process was used, and an exposure for five seconds was required when

bright sunlight was used for illumination. With such brilliant light it was found impossible to photograph the human eye, but by using cats which were anesthetized with chloroform and whose pupils had been dilated with atropine, he secured photographs of the fundus oculi. This apparatus could also be used as an ophthalmoscope if a kerosene lamp was used for illumination, and a ground glass replaced the photographic plate. Roseburgh mentions troublesome reflections from the cornea and surfaces of the lenses, which interfered greatly both in photographing the eyes of cats and in examining the human eye. These reflexes or "flares" have proven most troublesome in all attempts at fundus photography, and many of the subsequent efforts of investigators were directed toward the problem of their elimination.

The apparatus of Roseburgh was modified in 1880, by Liebreich, who used a perforated mirror instead of a plane glass to reflect light through the pupil. The perforated mirror for the examination of the fundus was devised by Helmholtz in 1852, and was subsequently used extensively by the pioneer ophthalmologist Albrecht von Graefe. It was a simple matter to combine this with the camera for photography. Liebreich's apparatus is shown in Fig. 12. A metal concave mirror 11 mm in diameter with a perforation located at its center, reflected light through the pupil and onto the retina, while a lens located immediately behind the perforation in the mirror projected the image to a photographic plate. The pupil was dilated with atropine, and an arc light magnesium light or the sun was used for illumination. The eye was in some measure protected from this brilliant illumination by a blue-violet glass or a cell containing a solution of ammoniacal copper oxide, located in the tube between the mirror and the eye. Exposures of ¼ to 2 seconds were required, and a picture 1 to 3 cm in diameter was produced, depending on the lens system used.

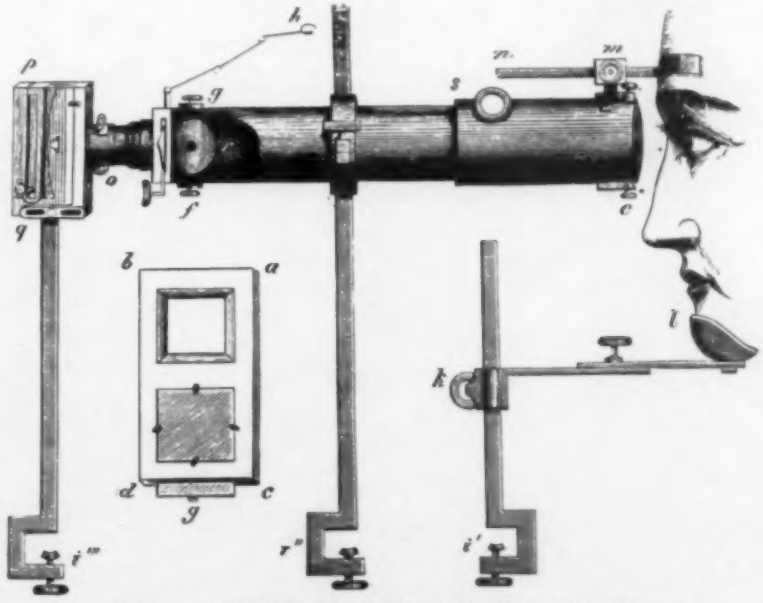

FIG. 12. PHOTOGRAPHIC OPHTHALMOSCOPE

USED IN 1880 BY LIEBREICH. A PERFORATED MIRROR AT "R" REFLECTED LIGHT INTO THE EYE. THE CAMERA IS AT "PQ" WITH ITS LENS AT "O."

Flares or reflexes were not the only obstacles encountered in photographing the fundus oculi. The reddish hue of the retina necessitated extremely long exposures with the red-blind emulsions. To overcome this, Barr in 1887 used plates which he bathed in a solution of erythrosin, silver chloride and ammonium hydroxide to increase their sensitivity to the red color. This was a material aid, but the problem of illumination was still a difficult one. The retina is too sensitive to be subjected to excessive illumination, and yet an unusually large amount of light is required for photographic purposes.

This problem appears to have been solved by the use of a brilliant flash of light furnishing an intense illumination for a short period during which the film or plate is exposed. Guilloz in 1893 focused the camera and arranged his mirrors and lenses by means of a gas lamp, the light of which did not injure the eyes. After proper adjustments had been made a magnesium mixture was pushed into the flame giving a flash for the exposure. A similar arrangement was used in 1902 by Thorner, who aligned the flash and adjusting lamp so that after the image was focused properly the flash illuminated the same field as the lamp. Friedrich Dimmer, in the same year, used a brilliant arc, the light of which was obstructed by means of an opaque glass and when the shutter was tripped the glass was momentarily drawn aside.

In the illumination of the retina Thorner and Dimmer attempted to eliminate flares, by projecting a beam of light through only a portion of the pupil, leaving the central part for photographic purposes. This principle, as it was finally developed in the Nordensen camera of the present time, has made it possible to eliminate these flares almost entirely and, as a result, the photography of the fundus oculi has reached its perfection. With the Nordensen camera many beautiful studies of the fundus oculi have been made—studies which even surpass drawings and sketches in their value for teaching and record.

THE EMERGENCE OF THE CICADA

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AFTER spending almost seventeen years underground, undergoing various stages of development, the emergence of the cicada (*Cicada septemdecim* or so-called seventeen-year locust) from its yellowish-brown semitransparent shell is

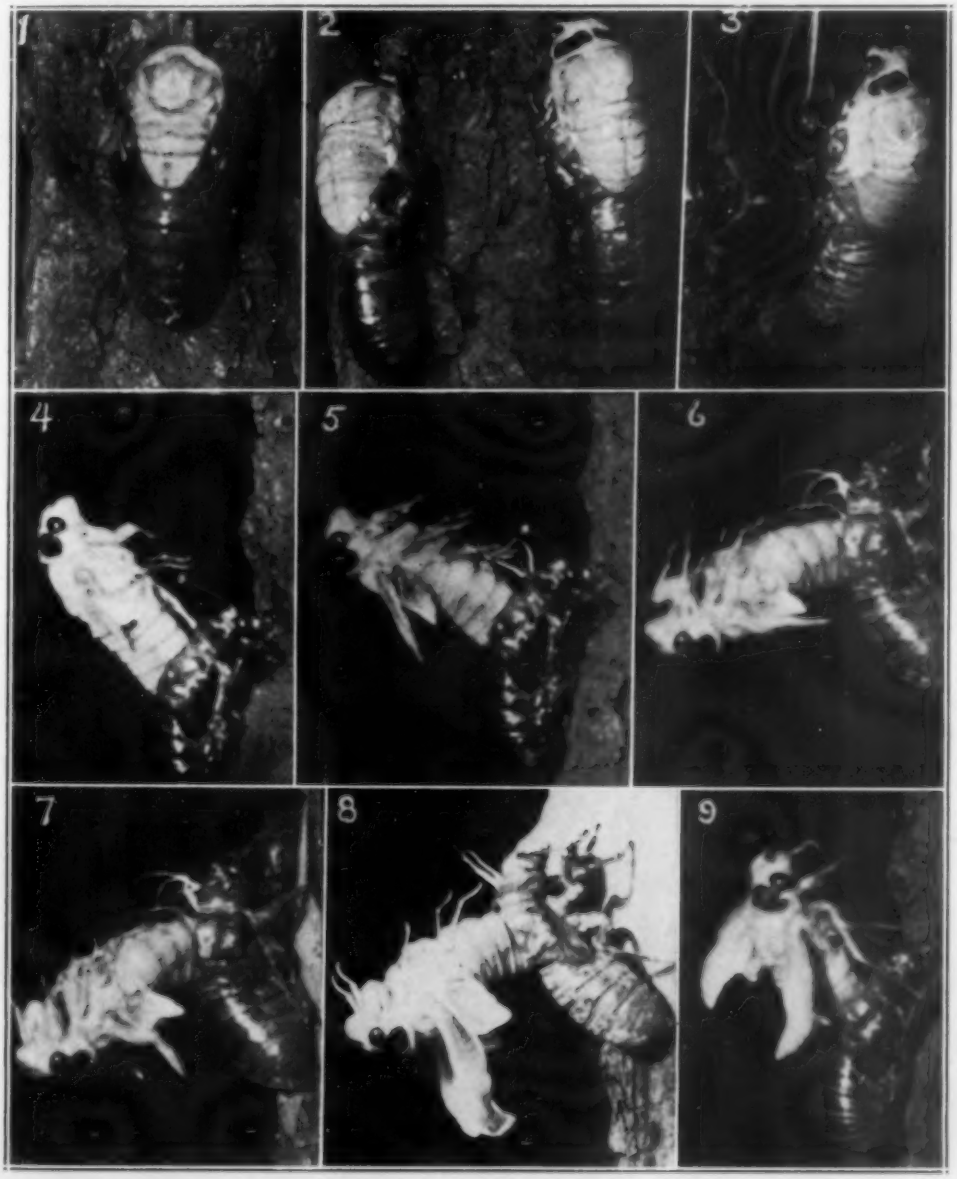

PLATE 1.

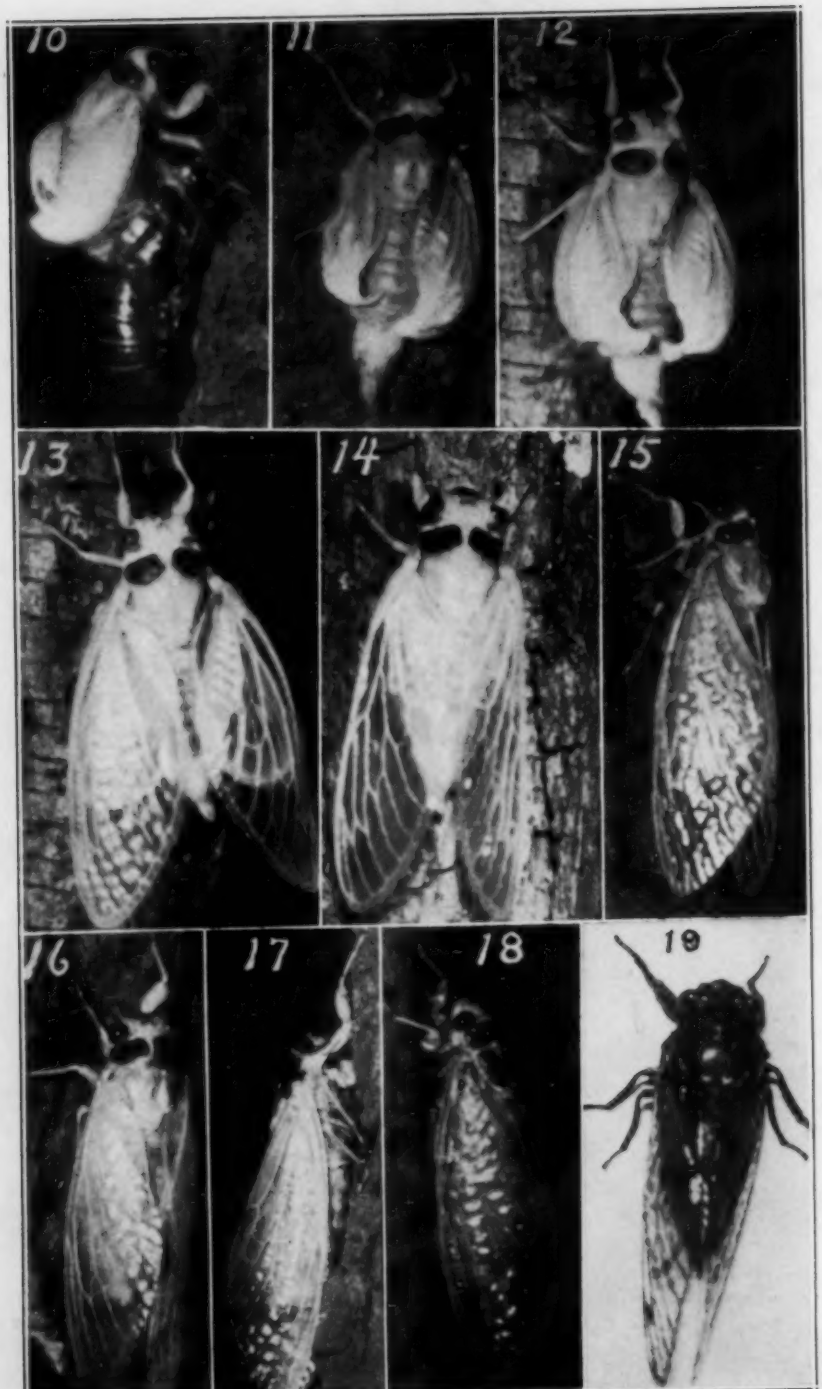

PLATE 2.

an occurrence that enthralls all who have an opportunity to watch the event.

Having plenty of specimens available in my back yard, and finding so many persons, young and old, interested, once their attention was called to this phenomenon, it was instructive to secure a photographic record of this transition.

Although the emergence of the adult from the shell is a fairly continuous and orderly process, there are several distinct phases that are worthy of description.

First let us consider the exit from the ground. This occurs under trees (beeches, oaks, etc.) or places where there had been trees, the young, succulent branches of which had served as a depository for the eggs seventeen years earlier.

Having spent all this time underground, undergoing the usual morphosis from larva to pupa, we found immature specimens of the latter while setting out bushes some three years ago, and again early in March and April of this year. Early in May some of the more hardy ones dug holes to the surface and waited for a warm evening to come out of their subterranean abode. It was interesting to watch them just beneath the surface, and, if disturbed, see them drop down about two inches underground, where they rested, secure from birds.

The exit from underground occurred at sundown, or even earlier in the shaded part of a woods. The dry leaves fairly crackled as a dozen or more crawled toward the host tree, which some mounted to a height of ten to thirty feet. Late-comers settled on the trunk or mounted small bushes—anything that provided a good toe-hold, which is an important item in the emergence from the hard shell.

The propitious time for bursting and emerging from the chitinous casing having arrived, the ceremony preceding the event consists in rubbing the thick femora of the fore-legs over each other, then stroking the antennae with the fore-legs and sometimes stroking the sides of the abdomen with the hind legs.

Apparently this ritual is for the purpose of limbering up and facilitating the withdrawal of these organs from their hard casing — an important detail, judged by the high mortality as indicated by the number of insects that succeeded in bursting the outer casing, but failed to withdraw the head and died in armor.

On completion of the massaging ceremony the insect proceeds very deliberately to sink its sharp-hooked claws into the underside of a leaf or the side of a tree upon which it is resting—but always in such a position that, after partial emergence, the body hangs with the head away from the shell, back downward, so that the wings can expand freely—presumably assisted by the action of gravity (see Fig. 8).

How does the insect burst its shell? That is an interesting event. Firmly attached to the leaf or bark by means of the sharp claws of its six feet, it proceeds to draw the terminal part of the abdomen toward the central part of the casing. This is a step-by-step, wave-like process, as the segments of the casing expand, radially, in succession, from the tip of the center of the body. This puts great pressure in the region of the thorax, which bursts the casing at this point (see Fig. 1). The round appearance of the casing, after emergence of the insect, as differing from the flat abdomen before fracture of the shell, is well illustrated in Fig. 2. In one instance the insect worked perhaps fifteen minutes and, not succeeding in breaking the shell, suddenly walked off, leaving

me to find another specimen to photograph.

Once the casing is broken the first stage of the emergence proceeds rapidly. In the course of a few minutes the part of the thorax containing the two conspicuous black spots appears. Then the beautiful light-colored, orange-red eyes appear (Fig. 2). Notice the unfolded wing extending under the translucent sheath.

After further pulling (action shown in Fig. 2) the front legs are withdrawn (Fig. 3) and the insect swings back, as shown in Fig. 4. In this position some half a dozen filaments ("guy ropes") attached to the sides and beneath the thorax are visible. After some kicking the hind legs are free (Fig. 5).

In the course of five to ten minutes after swinging freely (Fig. 5) back downward, the small orange-yellow masses (wings) at the sides partially unfold (Fig. 6), and movements are visible as the wings continue to expand (Figs. 7 and 8).

After the wings have partly unfolded the insect raises itself upward and forward (Fig. 9) over its shell, which it grips with its front feet, and proceeds to pull the rear end of its body out of the casing. This is a very active period, and sometimes it involves quite a struggle to release the abdomen. In Fig. 10 the insect is shown pulling with its fore-feet, trying to free its abdomen from the shell. By gently tapping its head with the finger I succeeded in inducing the insect to remain quiet long enough (one second) to secure a fairly clear picture.

Once released, the insect clings to its shell with its two sharp-clawed front feet, and swings its body free from its former armor. This allows its wings to expand. The various stages are shown in Figs. 11 to 13.

In this stage the wings have a faint bluish-white glow, under a flashlight, and the outer vein is a light yellowish tint. In the early stages, the diaphanous membranes of the wings, between the veins, are bulged upward, giving the peculiar spottedness in the photograph (Fig. 13). As the veins expand and harden, these membranes become more taut. As the outer vein becomes hardened the wing folds closer to the body (Figs. 14, 15, 16).

The rest of the body is, of course, white, except the two black spots on the thorax, which are conspicuous from the very beginning of emergence (Fig. 2). On first emergence the rest of the thorax appears a silky, faint-pinkish, white (Figs. 1 to 3).

The complete emergence requires about thirty to forty minutes. In the course of the next hour or two the body of the insect grows darker and darker, and by the following morning it is entirely black (Figs. 16 to 19).

If the English sparrows, gray squirrels, crows, etc., do not get him, he is then ready to fly to the highest tree-top, where, by raising the tip of his abdomen, he emits his famous "A-a-a-a-a-o" note, which he repeats three to five times, and then pauses for a short rest. The last part of the note is much fainter and occurs when he drops his abdomen—apparently his vibrator is not properly damped.

Only the male sings. The female is unable, and hasn't the time to sing. She is busy with her lance-tipped ovipositor puncturing this year's growth of succulent tips of trees and depositing several hundred tiny white eggs, which in the course of a few weeks hatch into larvae that drop to the ground, to begin a new cycle of sixteen years of burrowing beneath the surface, feeding upon the root-juices of vegetation; then, after a brief

existence as pupae, emerge from the ground in 1953. In the meantime, owing to the lack of sunshine, let us hope the mortality from rickets is not too great. Certainly they are not a good advertisement for the advocates of vitamin D, irradiated food, etc.

Just why this interesting insect is doomed to a life of digging underground for almost seventeen years is an interesting question. Most other insects complete their cycle from egg to larva, pupa and maturity in from a few months to a year. Even his cousin the lyreman (*cicada tibicen*) appears biennially, with a different brood maturing yearly to enliven the hot August days with his shrill notes.

But if nature has doomed him to digging for 16 plus years, it has provided him with suitable tools in the form of a pair of thick-clawed, fossorial anterior legs.

Hatching from a spindle-shaped egg, about 2.5 mm. long and about one tenth that size in diameter, the most conspicuous part of the larva is the long antennae, the pin-point sized dark eyes (why eyes if he must work underground?) and the heavy-femured fore-legs, ready for digging. Excepting for the lack of wing pads and the presence of unusually long antennae, the freshly emerged larva is not unlike the encased insect shown in the photographs.

In spite of its extremely fragile appearance, the newly hatched insect, if given the opportunity, at once proceeds to dig in, and in a few minutes has disappeared underground. This is a story in itself to those interested in the subject.

From sticks containing eggs, picked up under trees, the writer has had pleasure in watching the process of development of the egg from an undifferentiated white spindle to the stage when it became tipped with two dark specks (the eyes). The spindle then began to vibrate, to and fro; and the larva broke open the casing and emerged. From these dry branches over 600 larvae were hatched, controverting the popular belief that the sap in the tree is a necessity to development of the egg.

My first experience with the cicada was as a boy of nine; they were "locusts" and I was not allowed to go barefooted "because they would sting." I was told also that they sang "Pharaoh" and the "W" on the wing meant "war." Well, we have had plenty of war, within and outside the locust season. The "W," "M" or more likely "N" is visible near the tip of the wing (in Fig. 19).

THE TRENDS IN MODERN GENETICS

AN EVALUATION OF CURRENT RESEARCHES

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GENETICS is that branch of science which investigates the origin, the development and the heredity of traits or qualities which, in the aggregate, constitute the inborn endowments of living organisms—plants, animals and men. Genetics involves also the study of the mechanism, the chemistry and the physiology of reproduction, and finally it concerns studies on the origin and evolution of species, and on those forces—both internal and external—which effect the rise and fall of racial stocks.

A generation has passed since genetics established itself as a definite scientific discipline. The foundation story can now be told from a historical point of view.

Since the basic purpose of genetical research is to seek the truth about the inheritance of definite qualities in plants, animals and man, using all methods and tools available, the questions arise: What are the main problems which now call for definite research in this science? Among these problems, what is their relative value in terms of chance of profitable discovery about genetical principles or in filling gaps in existing knowledge? In view of the present status of the science of genetics as a whole and of the facilities and resources available, to what relative emphasis is each line of current genetical research entitled? The specific purpose of the present paper is to make such a short but critical review and to take stock of its lessons.

As an art genetics is very old. As a modern science it is new and still finding itself. As a pure science genetics grew out of more definitely controlled and better understood experiments in breeding. These experiments had for their main purpose the improvement of domestic varieties of plants and animals for man's use. The great impetus to research in many phases of organic evolution which science received a generation ago was due to the fortunate interaction of a number of things: First, there must be listed the general appreciation of the principle of evolution as a general rule in the organic world; second, the practical increase in numbers, specialization and blood-purity of varieties of domestic plants and animals, and the better understanding of both the basic principles and the practical rules by which husbandmen accomplished breed-improvement of their domestic stocks; third, the rediscovery of Mendelian principles in 1900; fourth, the general advance in analytical methods and laboratory technique in biological study, particularly the advance in cytology, embryology, biochemistry, physiology and psychology; and fifth, the more critical application of mathematical analysis to research in biology, including the demand for more accurate and quantitative measures, that is, for better yardsticks for the specific qualities under genetical investigation. All these factors interacted to advance rapidly the effective organization of the science of genetics, as the more critical study of the origin, the development and the heredity of the constitutional or inborn qualities in plants, animals and man had come to be known.

Judged from past history and present status, in the following paragraphs we shall list briefly the principal subjects of genetical study, list the trends of re-

search, attempt briefly to evaluate the contributions of each line of study and to indicate the most profitable lines of genetical research for the immediate future.

(1) Heredity and Environment

Heredity and environment have, for many generations, been the subjects of long and warm debate. These debates have argued both pro and con: Which is more important, or which plays the greater rôle in the individual's status—heredity or environment? Or, to be more specific: In a given case just what part has heredity played and just what part has environment played in producing the particular end-result, the qualities but not the causes of which no one doubts?

The truth seems that in every individual plant or animal at every stage in the individual's development, from the single cell to death from old age, such individual status is the resultant of the interaction of heredity and environment. These relative influences are rarely the same. In some qualities heredity seems to have been the controlling influence and in others environment. But the basic substances, structures and qualities on which environment must work are furnished by heredity. Whether the particular egg will develop into a mouse or a rat depends upon heredity; if a mouse, whether white or gray, again depends upon heredity; and if a white mouse, whether specially susceptible or resistant to some diseases, such as rickets, depends about 50–50 on heredity and environment. Hereditary resistance or susceptibility, which latter is resistance at the negative end of the scale, seems to be, in this case, acted upon by nutrition differentially among different family stocks.

An essential part of the clear statement of every problem in genetics consists in provision for the relative evaluation of heredity and environment before the more specific genetic problems are attacked. Science still needs many more specific data before it can generalize more satisfactorily on the heredity-environment problem.

(2) The Mechanism of Heredity

The special phenomena of heredity were found to parallel closely the special cytological phenomena found in the duplication, reduction, segregation and recombination of chromosomes and parts of chromosomes in the preparation of the egg and the sperm for union in bi-sexual heredity. This mechanism managed beautifully to prevent the piling up of chromosomes in bi-sexual heredity. The Mendelian rules, based upon the somatic ratios in the offspring, thus squared with both the distribution-ratios of the same definite somatic qualities among their ancestors and with the chromosomal mechanism seen by the cytologist. These principles involve the concept of segregable units of heredity quite comparable, indeed, with the atom-concept in chemistry—the principle of segregation and recombination. In certain cases and in some forms of plants and animals the rule worked to perfection, so that with the parallel development of definite knowledge about the mechanism of chromosomal duplication, segregation and recombination in the germ cells, a mechanism was found which explained the basic phenomena of heredity.

Experimentation followed with many traits and qualities in many species and varieties of plants and animals and in many races and family-stocks of man—all seeking the needed "atom"—the unit of heredity. Thus the mechanism of heredity seen by the cytologist and the mathematical ratios of actual traits seen by the breeder in the Mendelian laboratories tied up so well that at one time the whole problem seemed solved. Much

basic truth had been found, but the final generality which the beautiful tie-up promised was too simple and definite to tell the whole story. The main difficulty seemed to be that, while the unit-concept in heredity served a great use as did the "uncutable atom" in chemistry, it was so fixed a concept that it tended also to obstruct progress along other lines.

(3) Mutation

As a general rule experimentalists have not yet been able to show whether or when a mutation, which is a definite hereditary change in the species, is due to a chemical change in the nature of the gene or a portion of the chromosome, to a positional shift of chromosomes or parts thereof, or simply to different chromosomal combinations in egg and sperm, causing repeatedly a new but constant outcome in somatic development.

Thus the genetics of segregable units of heredity is not the whole of genetics, promising as it seemed for a time. The behavior of many hereditary traits found by experimental and practical breeding resulted in the discovery that most such definitely diagnosable or measurable traits which are the basis of breed-improvement in plants, animals and man, are not based on single Mendelian units, but are instead exceedingly complex—like "giant molecules." They are hereditary—they run-in-the-family, but they are complex. Finding the rules which determine the inheritance of each such quality—whether structural, chemical, physiological or psychological—whether in plants, animals or man—whether in single-celled organisms or in the highest primates—still presents the great problem of genetics which deserves relatively more attention.

(4) The Gene Concept

The gene concept marks an important mile-post in genetical progress. A single gene can not be conceived as affecting only one somatic trait—one gene must certainly affect many somatic traits. Nor can one resultant in the soma be thought of as having been developed by or out of a single gene. Such a trait or somatic quality is the resultant of the interaction of a great host of genes, or chromosomal particles, if that definition be held for the time being.

There are now two senses in which the word "gene" is used, each of which is essentially different from the other. First, the gene may be conceived of as the smallest physical particle of the chromosome—possibly visible under the best microscope. Second, the gene may be thought of as the chemical and structural forerunner in the fertilized egg of a given trait or quality in the adult. Tracing the development of this gene to the quality itself in the adult is a long process, and, in its very early stages, has never been satisfactorily accomplished without serious gaps. Such a gene must be responsible solely for one trait and none other in the mature body.

But, as earlier stated, most of the qualities of the adult which are measurable or definitely diagnosable and are of use in plant and animal breeding and in human genetics and eugenics are not based upon a single or only a few genes, but more likely upon many hundreds of genes. Thus the effect of one gene or hereditary determiner is not constant, but is conditioned and determined by the particular combination with other genes in reference to the time and place of these unions as well as the chemical nature of the genes themselves.

(5) The Gap Between the Gene and the Primordium

There is at present a long gap in our knowledge along the stretch of developmental sequence from the gene to the first sign of a definite tissue or organ in the embryo. What is and where is the thing which represents the subse-

quent trait, tissue or organ from the time it was last seen, as a gene in the germ cell or fertilized egg, until its reappearance as the "anlage" for said quality, tissue or organ in the embryo? This long gap leaves the relation of the gene and the chromosome to heredity still without its major support. Success in this field seems clearly to demand a joint attack by genetics and embryology. Embryology seeks continued sequence in development.

Biology demands still further collaborative research to find out whether the chromosome and its constituent genes (or at least the giant molecules or colloidal particles that appear to be genes) actually develop into or are otherwise responsible for the somatic traits or organs, as the science of cytogenetics now postulates. Even if no such "gene — trait sequence" were found, each of the basic sciences concerned would profit substantially by a collaborative hunt and each would continue to constitute a basic science in its own right.

The major joint task for genetics and embryology during the next period of scientific study is work in this particular field. If, ultimately, such joint studies work out as postulated by the cyto-geneticist, and numerous high points in this series are found, then the theory of the gene would stand as a principle, essentially in its present form, even if modified in detail. But if, after long search, such a "gene—trait sequence" could not be found, then the theory of the gene would be greatly weakened, and some other major explanation would have to be found for the mechanical basis of the heredity-pattern and also for the things and processes which might be found in the present developmental gap.

(6) The Functions of the Nucleus

The chromosomes have three primary functions: (1) to reproduce themselves exactly and thus insure continuity of the germ-plasm; (2) to prompt and guide the individual ontogeny to its somatic end; and (3) as a major body of molecules in the cell to give chemical and structural character and specific physiology to the cell as a unit in some highly specialized organ.

In duplication exact maintenance of chemical and structural character must be maintained in one cell-generation after another. In ontogeny the cell, beginning with the fertilized egg, must have the potentiality of developing along definite lines under definite conditions, but in its somatic end-tissue the nucleus, then highly specialized, has lost the power to reproduce itself, has reached a "blind alley," so to speak, but is vitally essential physiologically to the organism. The salivary glands of the fruit-fly are a good example of such a "blind alley." These several functions of the nucleus, along with the functions of the cytoplasm, are major fields for current genetical study.

(7) The Measure of Hereditary Traits and Qualities. Yardstick Invention

Because most of the traits or qualities which concern organic evolution and heredity—and consequently are the basic elements with which mate-selection and the creation, rise and disappearance of species depend—are not single Mendelian units, nor even small groups of such units, but in the body of the individual are structural or functional qualities which for their somatic development depend upon the interaction of great masses of genes, such fact does not eliminate the necessity to describe and to define as a whole the somatic trait or quality under consideration; then to apply to it the principles of identification and diagnosis; then to apply the yardstick for its definite measure. This is no small task. It must be remembered that

it required several thousand years of hard study by the whole human race to invent the more elementary yardsticks for the basic qualities of time, weight and distance—the c.g.s. system of modern physics.

The measure of a hereditary quality in the individual may be accomplished by one of the following ways: (a) Mathematical yardstick; (b) Matching-standards; (c) Description — definite diagnosis and case history.

Genetics can make no substantial headway unless the hereditary quality in the individual is measurable or diagnosable with some degree of definiteness. Of course, the ideal situation would call for the application of an accurate mathematical yardstick, which would measure exactly the degree of development of the subject-trait in a relative scale from zero to one, or on an arbitrary but absolute scale of equal accuracy.

Lacking such a yardstick, the next best genetical standard might be called the "matching-standard" in which a complicated anatomical or physiological or psychological quality of definite development is described, or a picture of it is set up as a standard against which the appearance of the same quality in a particular individual in a particular pedigree may be matched. The group of such matching-standards should comprise at least "two, three or five" or preferably more definite structural or conditional degrees of the same thing.

The third type of measure or standard might be called simply the definite diagnosis and case history. In this case the individual is described as having the quality or having it not. In the case of human stature, if the yardstick in inches or centimeters were lacking, and there were no individual against whom the particular measured person could be matched for height, the subject might be described for height as (1) dwarf, (2) short, (3) medium, (4) tall or (5) giant. In the development of yardsticks for genetical use it is well, with the lack of a mathematical yardstick, to proceed toward definite standards—advancing from descriptive classes, to matching-standards and, finally, when possible to the mathematical yardstick.

In genetical research great stress has quite properly been placed upon chromosomal study, but not enough upon the exact quantitative measurement or description or classification of those definite somatic qualities which are known to run-in-the-family. Practically it is necessary to know to what extent hereditary qualities can be broken up and recombined in heredity. It is necessary also to find the actual "breeding-units," whether or not practical breeding has yet learned to segregate them.

The whole matter of measurement comes in at this point. It is necessary first to measure the somatic end-product with which we are concerned both in theoretical study and in practical breed-improvement. Sir Francis Galton, one of the real founders of modern statistical science as an important department of applied biology, particularly in his use of mathematics as a research tool, was fond of saying:

> Until the phenomena of any branch of knowledge have been submitted to measurement and number it can not assume the status and dignity of a science.

(8) Truth and Probability

The philosophers have fought long and valiantly over the question: "Do natural phenomena obey exact laws down to the very remotest and infinite detail, or does the creative principle itself require a breach of this behavior and thereupon place consciousness, appreciation and purpose as essential elements in the scheme of things?"

In nearly every field of scientific re-

search the two principal things, when exactness is desired, are first the yardstick and second, the principle of probability. The Mendelian principles which have added so much to our knowledge of nature's behavior in heredity, were based upon ratios which occurred, in certain cases, within a definite probability. But in the field of mathematical analysis, there exists temptation to base conclusions upon the weak foundation of too few numbers and too little exactness of observed fact. Discovery of biological truth may be hampered as greatly by inappropriate or too much mathematical analysis as by the sacred postulates of over-orthodoxy or by predrawn conclusions. The investigator, if not extremely careful, is apt to provide one function by analysis, then to take this and build other functions upon it. Thus the temptation is to use derived values instead of observed data as the basis to which the investigation comes back very frequently in its search for truth.

Nevertheless, there is a new and general appreciation of the principles of probability. For a long time it was thought that biology and inheritance were non-mathematical sciences; that physics, chemistry and astronomy were mathematical or exact sciences. It is found now that physics, chemistry and astronomy are less exact mathematically, that is, they depend more upon probability-mathematics than formerly thought, and that, moving in the other direction toward a common ground, the biological sciences, by depending more upon probability, are becoming more mathematical.

(9) The General Formula of Heredity

Mathematically stated, the main problem of genetics runs as follows: Given a measured quality in each of a certain group of near-blood-kin, by what probability will the pre-indicated offspring possess this same quality within a definitely measured class-range? Successful prediction in such a case depends mathematically upon the location of the fluctuation-center of measurable values in the thing-predicted and the narrowness of fluctuation above and below this center. The more exact the fluctuation center and the narrower the range of fluctuation, the better the prediction, and the more certainly will the computed probability be found to point toward truth.

All genetical predictions by mathematical analysis which seek a general rule of nature's behavior depend ultimately, as for example the Mendelian studies do, upon the somatic ratios of the given quality among certain definite near-blood-kin.

$$(10)\quad K = f(M, R)$$

This is the general mathematical picture of nature's behavior in transmitting a trait or quality from one generation to the next.

$K = f(M, R)$, that is, K is the probability that, with a given M or measured quality in a given ancestor as the prediction-basis, the measured value of this same quality in the offspring will fall within the value $R \pm$ one half the selected class-range.

Next to its biological basis the main thing in genetical study is mathematical analysis. In this latter field the purpose is to test postulates and to construct the best possible mathematical picture or pattern for tracing the behavior of nature in the transmission of measurable or diagnosable qualities from one generation of living organisms to the next. While $K = f(M, R)$ is the mathematical statement of the general formula of heredity, it is necessary in the case of each definitely measured trait in each species to find out just what these two functions are and how they work to-

gether. This has been done for the quality of racing capacity in the Thoroughbred horse. This quality, which is highly hereditary—it runs-in-the-family, after being definitely measured in the individual could be investigated most profitably from the genetic point of view.

(11) The Probability-Resultant

With this quality of racing capacity in the Thoroughbred horse it was possible to consider the matter of independence and synthesis of evidence. In this case the pattern formula of heredity —$K = f(M, R)$—first applied to the resemblance of measured racing capacity in the sire to measured racing capacity in the foal (all other near-kin being randomly represented), furnishes one definite element or piece of evidence.

Similar studies were made for each of the several nearest-blood-kin; it then became possible and feasible to work out the probability-resultant of all such pieces of independent evidence for the prediction of racing-capacity value for the offspring of any given specific set-up or group of near-blood-kin. Thus, given any pedigree set-up in reference to the same measurable or countable quality, and working out standards as the consequences of the analysis of at least 1,000 cases for each kinship, genetics has the basis for applying the general or pattern formula to the specific quality, and is thus able to compute the specific probabilities of given offspring-values when the measure of the subject-quality is given for each of the several near-blood-kin.

(12) Other Genetical Needs

While the evolutionary aspect of genetics as a controlled laboratory experimental problem is making headway, the coordination between genetics and both the paleontological and the more recent histories of the species of plants and animals have been relatively neglected. Similarly the collaboration of the laboratory geneticists with the practical breeders and improvers of plants and animals has been permitted to languish.

The two main characteristics of a living organism are reproduction and development. Of these the more fundamental is reproduction. In development a primitive cell may make undifferentiated colonies, then later may create specialized tissues and organs, but always the essential germ-plasm—the primitive cell—remains behind and is continuous. The most striking thing about a living cell is that its chemical activity, instead of creating some desired structure or starting a peculiar train of development (this is ontogeny), starts a train of chemical and structural reactions, the end-product of which is the exact duplicate of the cell which started the whole train. Thus the life cycle is represented in (a) reproduction of the germ cell, and in (b) the bizarre blind alley of somatic ontogeny. Genetical studies must keep this in mind always.

Still another relatively neglected field concerns the single-celled organisms, which have a different genetics from the many-celled species. The germ-cell and the somatic cell in single-celled organisms are the same. Thus single-cell genetics offers a field of research which should be pursued more extensively as a well-integrated unit of study within the field of genetics.

One degree down the scale of living forms below the single-cell organisms brings us to the virus, which now seems to be proven to consist of definite chemicals, the unit of which is a giant molecule of some sort. This molecule seems to have one of the main essential properties of living matter in that, under proper environment, the virus-molecule

can duplicate itself, like a catalyzer or enzyme which makes itself. The relation of the behavior of the viruses, as recent discoveries have shown, offer a promising lead for more fundamental studies in the common field of bio-chemistry, pathology and genetics.

(13) The Relation of Genetics to Other Science

If genetics fulfils its basic purpose, its fundamental researches will always be made in two fields: First, in experimental breeding and, second, in the study of natural evolution. Among the most essential tools needed for the interpretation of genetic data found by experimental breeding are the techniques worked out by the allied sciences of cytology, biochemistry, embryology, mathematics, paleontology and natural history. Pathology, psychology and education should be included in this list of critical sciences of use here.

The relation of genetics to eugenics is very close, but eugenics can not be looked upon as merely a branch of genetics. At the beginning of the century, along with the development of genetics as a science, and inspired mainly by the work of Sir Francis Galton and his colleagues, the general rules of heredity began to be tested for definite traits in man, and thus the foundation was laid for eugenics as "the study of all agencies under social control, that may improve or impair the racial qualities of future generations either physically or mentally."

(14) Relative Emphasis and Profitable Trends in Genetics

While genetics and eugenics have not always followed and are not now emphasizing equably what are probably the most profitable phases of research in both pure and applied fields, still their net work has been exceedingly profitable in the discovery of truth, and to list the main lines only, the following fields of study are becoming more equably emphasized by research institutions and colleges:

Researches on:

(a) The basic Mendelian principles. "The theory of the gene." Specific cases.
(b) The chemical and physical nature of the gene.
(c) The biochemistry of genetics and development. The hereditary or constitutional aspects of immunity and susceptibility.
(d) The induction of mutations, and the manipulation of chromosomes.
(e) Bridging the gap by a more continuous picture between the gene and the first sign of the specific structure or organ in embryological life.
(f) Yardstick invention and more definite diagnostic descriptions of traits and qualities, whether by measure, or by clean-cut definition, or by matching standard.
(g) The construction of correct mathematical pictures which show how nature behaves in the control of genetical processes, looking to the discovery of generalized rules which may tie up still more closely the predictable somatic ratios in pedigree-analysis with the reproductive and developmental machinery.

BEGINNINGS OF FISH TERATOLOGY, 1555–1642

BELON, RONDELET, GESNER AND ALDROVANDI, THE FATHERS OF ICHTHYOLOGY, THE FIRST TO FIGURE ABNORMAL FISHES

By Dr. E. W. GUDGER

BIBLIOGRAPHER AND ASSOCIATE CURATOR OF FISHES, AMERICAN MUSEUM OF NATURAL HISTORY

Introduction

For the present writer it all goes back to a certain afternoon in the autumn of 1901, when, a graduate student at the Johns Hopkins University, I sat at work in the general laboratory of the old biology building at the corner of Eutaw and Little Ross Streets in Baltimore. I was working late dissecting the head of a skate to get the blood vessel system, and what I found was not "like the book." Inexperienced, I worked and worried (all by myself) but could not find the blood vessels with bends and curves and positions as described and figured in "the book" I was using as a guide—and I became considerably disturbed.

My equanimity was not heightened by the fact that about every fifteen minutes the janitor, who was wanting to close the laboratory and go home, would come to the big double doors, jingle his keys suggestively and look at me reproachfully. Each time I hurled objurgatory remarks at him and each time he retreated. Finally, however, footsteps came and halted in the doorway. Exasperated at both skate and janitor, I said in no very pleasant tones: "Confound you, Gardner! I'll quit and go home. I can't get the darned thing to agree with the book."

Then I was paralyzed by a mild voice which said, "What's wrong, Gudger? Maybe I can help you." And looking around I saw Professor E. A. Andrews. Thirty feet away was a chute to the lower regions through which we dumped the debris of our dissections for disposal in the furnace. Had it not been so distant and so small, I think that in my extreme embarrassment I should surely have risked this rapid transit *ad advernum*.

Professor Andrews then came over, looked at my dissection showing the course of the blood vessels, and said: "The figures in the book you are using may be made from a specimen dissected by the author, but more likely they are generalized diagrams intended to fit the majority of cases. What you have is a very interesting abnormality, a marked departure from the normal." That settled the question for me, and from that day till this, I've been looking for such departures from the ordinary and it is great sport.

Abnormal Fishes Figured in the Old Fish Books

The beginnings of our knowledge of any phenomenon in natural history go far back in the past, and the ultimate origins can of course never be found, but the proximate ones sometimes can. Who first figured fish abnormalities can not be stated, but I have found who first published figures of such. Into this history I purpose leading my readers, in the hope that they may share my interest in this "good hunting."

Eighteen years after the episode narrated above I came to the American Museum as editor to bring to completion Dr. Bashford Dean's great "Bibliography of Fishes." Before his untimely death, my distinguished predecessor, Dr. C. R. Eastman, had brought out Volumes I and II and had most ably begun a very

fascinating section of Volume III, the "Pre-Linnaean" literature of fishes. This was to be a special bibliography of the old published writings on fishes from the *editio princeps* of Pliny's "Historia Naturalis" from the press of J. Spira at Venice in 1469 to the appearance at Stockholm in 1758–59 of the two volumes of the tenth edition of Linnaeus's "Systema Naturae." This great work on the nomenclature of animals, in its tenth edition is everywhere accepted as the international date line in zoology, separating the old from the modern, and establishing recognized names for animals and plants as of that date—1758–59.

This "bibliographing" the old literature of fishes opened to me a most fascinating field for exploration and study, and into its wide expanse I have in the years since 1919 made many happy incursions. Into one little corner of this little explored territory—that marked "Teratology or Study of Abnormal Fishes"—I now purpose taking the reader in the strong hope that he may find in it some of the interest I have.

In the first quarter of the 1500's, and indeed in the brief space of 15 years (1507–1522), there were born in southwestern Europe five men who were destined to set new standards for the study of natural history in the western world. Of most interest to me is the fact that these five established the science of ichthyology on the deep and broad and solid foundations on which we are building to-day. Of these men (Belon and Rondelet, Frenchmen; Gesner, a German-Swiss; and Salviani and Aldrovandi, Italians) and their work and books on fishes I have given some account in *Isis* (1935, vol. 22, no. 63, pp. 21–40, 5 portraits). Here and now I wish to show that four of them (all unknowingly) first figured and described abnormal fishes, and—375 years later—started the present writer in an extensive study of all sorts of fish abnormalities. Perhaps these beginnings may have some interest for the reader even as for the present writer.

A Salmon with a Hooked Lower Jaw, 1553

The first of these old naturalists, Pierre Belon, published in Paris in 1551 the first book ever devoted to fishes and having such a title page. Only ten fishes are described and figured—in crude but perfectly recognizable wood cuts—the first published figures of fishes known to me. However, the greater part of the book is given to the "Daulphin," to the hippopotamus and the nautilus—since in those early days all water dwellers were grouped together. Really the fishes are the smaller part of the book.

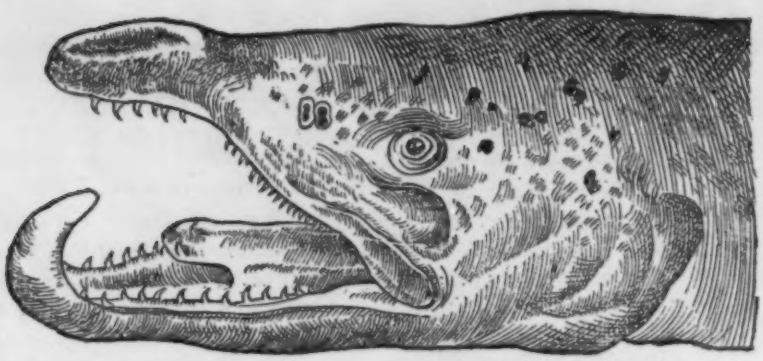
Two years later Belon published an enlargement of this work with a quaint title as follows:

Petri Bellonii Cenomani
De aquatilibus, Libri duo
Cum eiconibus ad viuam ipsorum effigiem, quoad eius fieri potuit expressis.
Ad amplissimum Cardinalem Castillionoeum
Parisiis.
Apud Carolum Stephanum, Typographum Regium.
M. D. LIII.
Cum privilegio Regis[1]

After another two years, Belon published as his ichthyological opus the third, the enlarged and final edition in his native French. The title is as follows:

La nature et diversité des poissons
avec leurs pourtraicts representez
au plus pres du naturel.[2]
Paris, 1555.

[1]Of Pierre Belon of LeMans
Two Books Dealing with Aquatic Animals,
With Effigies of These Drawn
As Near to Life as Possible
[Dedicated to] The Most Renowned
Cardinal Castillione
[Published] at Paris
At the Printing House of Charles Estienne,
Royal Printer.
1553
With the Permission of the King.



—*After Pierre Belon, 1553.*

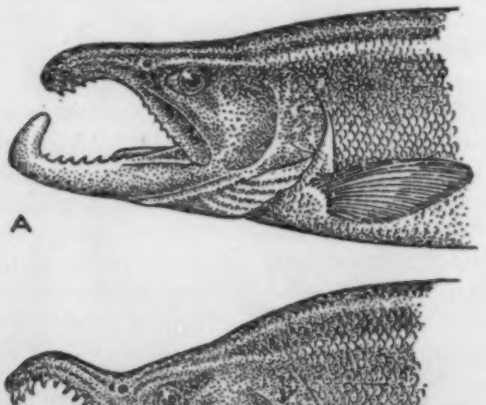
FIG. 1. THE HOOKED LOWER JAW

OF AN OLD MALE EUROPEAN SALMON. THIS IS THE FIRST PUBLISHED FIGURE OF A FISH ABNORMALITY.

These, the earliest books on fishes, are so old, so rare, and so valuable that they are literally "worth their weight in gold." Belon, who was an "all-round" naturalist, wrote other books on natural history subjects. His book on birds contains on opposite pages skeletons of bird and man with the like bones identified and labeled—the first known figures in comparative osteology. But let us return to the fishes, where our particular interests lie.

In both the 1553 and 1555 works, Belon figures the head of an old male salmon with the deformed upper and characteristic hooked lower jaw, as is to be seen in Fig. 1. This he thought to be the head of a female salmon, from which we may judge that he did not dissect his fish, since we now know that these de-

[2]The Nature and Diversity [Variety] of Fishes with their Portraits Represented as Near to Nature as Possible Paris, 1555.



—*After J. R. Norman, 1931.*

FIG. 2. HEADS SHOWING HOOKED JAWS

AT BREEDING SEASON OF (A) A MALE EUROPEAN AND (B) A MALE PACIFIC SALMON.

formed jaws are found on the male salmon only. The upper jaw in the Atlantic salmon undergoes only a moderate degree of deformity, as may be seen in Fig. 2A. But, as the drawing shows, in the Pacific salmon (Fig. 2B), the upper is even more deformed than the lower. Belon makes no remark on this deformity, and hence one may judge that he thought this the normal female head.

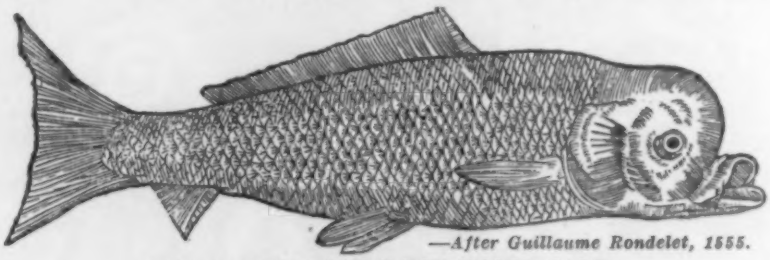
Little is known as to the cause of this abnormality. It is a secondary sex development at the time of reproductory activity. It develops at this time—at about the age of four years—in the Pacific salmon, and after spawning these fishes die. This is not true of the Atlantic salmon, which for a fish has a relatively long life span. Hence this curiously hooked lower jaw is very characteristic of old male Atlantic salmons, as may be seen in Fig. 2A. At the front of the upper jaw, in these salmons there is a groove formed in which the point of this hook fits.

The function of this peculiar hook is still in dispute. It was at one time thought that the male used it in making the so-called "nest" in pebbles and sand for the reception of the eggs. Then it was found that the female without a hook does most of this work. Next it was believed that the hook was used by the male to hold the female in spawning, but this idea also has been abandoned. Of it Smitt, the Scandinavian ichthyologist, writes: "The least violent explanation appears to be that the hook is an essentially pathological appearance, characteristic of age, but produced [in part] by the irritation caused by blows of the snout, both during combats and in leaping over obstacles."

It should be emphasized that this is the first published figure of a salmon with the hooked lower jaw, and the first figure ever published of a teratological (*i.e.*, deformed) fish. As such it is worthy of having particular attention called to it.

A Pug-Headed Carp, 1555

The second of our old ichthyologists was Guillaume Rondelet, regius professor and for the latter part of his life chancellor of the famous old medical school of Montpellier. This is only a few miles from the Mediterranean Sea, whose fishes Rondelet described.

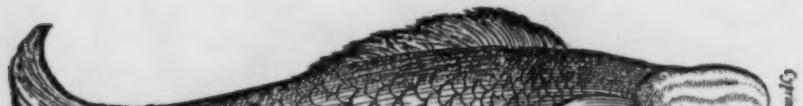


—After Guillaume Rondelet, 1555.

FIG. 3. RONDELET'S PUG-NOSED CARP.
THE FIRST PUBLISHED FIGURE OF THIS ABNORMALITY.

In 1554, Rondelet published at Lugduni[3] in quarto size his "Libri de Piscibus Marinis," in which 244 fishes are described and nearly all figured. In 1555, Rondelet published (also at Lyons) his "Universae aquatilium Historiae pars altera, cum veris ipsorum Imaginibus," which is a continuation of the 1554 work and is bound with it. In this book he figures salmons with faint beginnings of hooked jaws. Some of his figures are crude and several suggest abnormalities, but I can not be sure save of one of a carp now to be noted.

[3] Lugduni Gallorum—Lyons of the Gauls in France—is to be distinguished from Lugduni Batavorum—Leyden of the Batavians in Holland. Both cities were book-publishing centers of great activity in the 1500's.



—*After Conrad Gesner, 1558.*

FIG. 4. GESNER'S "CYPRINUS RARUS & MONSTROSUS."

THIS IS PRESUMABLY AN ATTEMPT TO PORTRAY A ROUND-HEADED CARP.

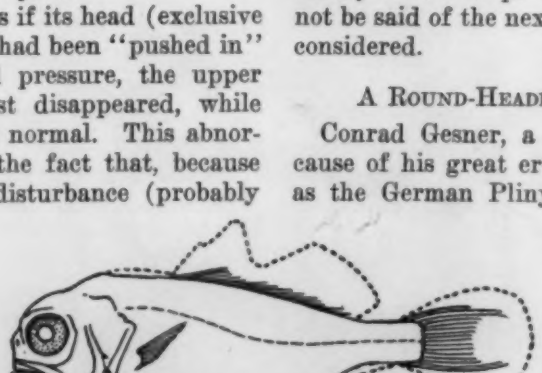
His "Cyprinus of a wonderful kind" (Fig. 3 herein) is the first published figure of a pug-headed fish. This fish, which our old doctor purchased alive at a fish market in Lyons, puzzled him greatly. It had the body, tail, fins, eyes, scales, etc., of a carp, but it had a bulging forehead and a very short upper jaw. Still, however, it was a carp, but as he thought and called it, "of a strange kind . . . with a snout like a dolphin." This abnormality bears characteristic designations as Bulldog-head, Pug-head, Lion-head; Tête de chien, Bouledogue Tête; Löwenkopf and Mopskopf—in the English, French and German languages, respectively. But in all cases the name applies to a fish with an abruptly rounded forehead, a very short upper but a normal lower jaw.

This fish looks as if its head (exclusive of the lower jaw) had been "pushed in" by strong frontal pressure, the upper jaw having almost disappeared, while the lower remains normal. This abnormality is due to the fact that, because of some internal disturbance (probably glandular) during development, the long bone forming the base of the skull fails to develop normally. This basal bone either fails to grow to normal length or it elongates but buckles up in the eye region, causing marked exophthalmia (protuberant eyes). In either case this ties down the bones which form the upper jaw and the anterior part of the skull, and results in the formation of the bulging forehead and abbreviated upper jaw.

This is the first published figure of a carp with a bulldog head, and the second of an abnormal fish. However crude some of Rondelet's woodcuts of fishes are, it must be said that this figure is a very good one—comparing favorably with some recent ones of this same abnormality in the carp. This, however, can not be said of the next abnormality to be considered.

A Round-Headed Carp, 1558

Conrad Gesner, a German-Swiss, because of his great erudition was known as the German Pliny. This cognomen



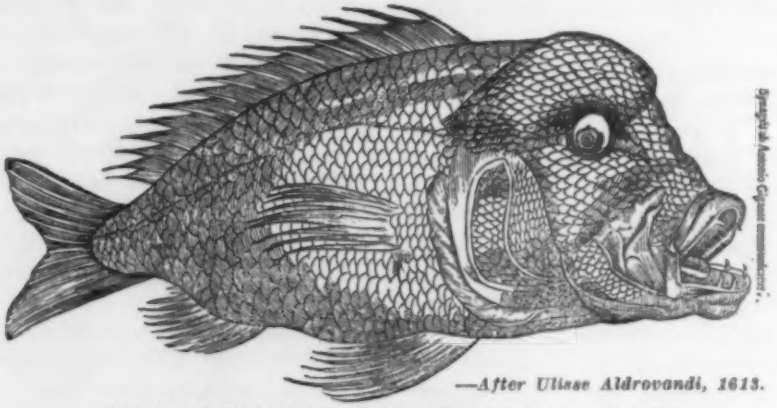
—*After E. W. Gudger, 1933.*

FIG. 5. A SMALL ROUND-HEADED MARINE PERCH (NATURAL SIZE).

was based in part on the publication at Zurich from 1551–87 of the five huge folio volumes (the last posthumously) of his great encyclopedic "Historia Animalium," in which was contained all that had been published up to his time plus all that he had learned of the natural history of animals in his travels and studies. Of this "Liber IIII"—"De Piscium & Aquatilium Animantium Natura"—is devoted to fishes and other water animals. These are arranged alphabetically and treated *in extenso*. Many of his figures and much of his data are taken from Belon and Rondelet—especially the latter.

figures, does he reproduce the figure of the pug-headed carp. However, as we shall see in the next section, he goes Rondelet not "one" but "several" better.

Gesner on p. 373 of his Liber IIII figures what he justifiably calls a "Cyprinus rarus & monstrosus." That he was wise in his choice of title may be seen on observing the fish portrayed in Fig. 4. Gesner also did not have this fish in his hands but only a painting of it sent to him by Achilles Pyrminius Gasserus, a physician of Augsburg. He expressly says that this fish, taken in November, 1545, from Lake Constance near Retz in



—*After Ulisse Aldrovandi, 1613.*

FIG. 6. ALDROVANDI'S FAT-HEADED SEA PERCH.

THE FIRST ILLUSTRATION OF THIS CURIOUS ANOMALY.

Gesner lists Rondelet's "Cyprinus mira specie" and gives his description. He declares that a similar pug-headed carp had been sent him by the classical scholar and writer Gilbertus Cognatus (Cousin), of Nozeroy in France, who had taken it in 1543 in a swamp and had kept it alive in an aquarium (the second alleged case of such—recall Rondelet's live specimen). The other was taken in Brandenburg, Germany, in 1546. This he did not receive, but he had a drawing of it sent to him by Johann Thannmyllerus of Augsburg. These fishes Gesner says were similar to Rondelet's, but he does not figure either fish, nor, after reproducing scores of Rondelet's other

western Austria, had a face like a human in forehead, eyes, mouth, nose, cheeks and chin. Another drawing of another similar malformed fish, taken in October, 1545, from the river Eirs near Retz, was sent to Gesner by Raphael Seiler, another Augsburg doctor. This drawing showed another carp which in its features "omnia effigie humana habuit."

Gesner's Latin is not easy to decipher, but I believe that I am quoting him correctly. He reiterates that these fishes were carps in everything but the front part of each head. These in forehead, eyes, nose, cheeks and chin had each a human aspect. And these things are just what are portrayed in Fig. 4.

—*After Jacques Pellegrin, 1901.*

FIG. 7.

A RECENT DRAWING OF ALDROVANDI'S FISH (*Dentex vulgaris*) WITH A HUMPED FOREHEAD.

It is not easy to explain this figure. Gesner was not given to credulity; on the other hand, his attitude was for his day thoroughly scientific. However, he evidently gave full credence to his correspondents. Note that both fish were taken near Retz in western Austria in successive months in the same year. It seems probable that there was but one fish. Gesner did not have the fishes themselves, only the drawings. Both drawings come from Augsburg, and it seems possible that one was a copy of the other. Some of the figures for his book were made by Gesner himself, the others in his house under his eye. But the woodcut of the "Cyprinus monstrosus" was evidently reproduced from one or the other of the drawings sent him.

But what was the carp with the human face, which Gesner knew only in a drawing? I do not know, but I suspect that it was that form of abnormal fish known to teratologists as a round-head. In such fishes the whole snout and anterior part of the skull fail to develop. Baby fishes in early stages have such an appearance, in which the whole front of the head is precipitously rounded off. If this early condition should persist into adult life, through the failure to develop of the bones forming the base of the skull and both jaws—lo a round-head similar to Gesner's figure.

That the interested reader may know what a real round-head looks like, there is reproduced here as Fig. 5 a drawing of such a fish which I had made some years ago. This is a little round-headed silver perch, only 2½ inches long, which has carried over to this age the round head and big eyes of his babyhood. If Gesner's fishes (which he did not see) were round-heads, then, since Gesner reproduced the drawing sent by his friend, it is clear that the artist drew heavily not on the fish but on his very strong and vivid imagination. And his product was such a fish as never was on land, in river or sea.

The fourth of our earliest ichthyologists was the Roman physician, Hippolyto Salviani. He wrote only on fishes —on those from the waters adjacent to Rome. His folio is illustrated by 77 brass (not copper) plate engravings. In the Museum copy these plates printed in 1554–1558 are as fresh and clear as if they had been struck off 38 instead of 380 years ago. Not one of them, however, shows an abnormal fish, so with this brief notice we pass on.

A GIBBOUS SEA PERCH, 1613

Next we consider the first published figure of a fish which may be designated as a "gibbous-head," a "hump-head" or a "fat-head." The names, like the abnormality, are interesting.

The word gibbous comes from the Latin *gibbus*, meaning a hump. It is primarily an astronomical term applied to the moon between half and full when the limbs are convex. In fishes a "frontal gibbosity" is what may be seen in Fig. 6 of the fish which the Italian encyclopedic naturalist, Aldrovandi, figures and describes under the name

Synagris in his "De Piscibus" (Bononiae [Bologna] 1613). This curious abnormality is not uncommon in certain perciform fishes of both fresh and salt water—of the families Cichlidae in fresh water and Labridae and Sparidae in salt water. Most of these fishes were once grouped as Chromidae, so-called because of their bright colors.

Like the hooked lower jaw found chiefly or only in the adult male salmon, and in the Atlantic salmon generally in exaggerated condition in old males only, frontal gibbosity is found only in adult males (and in more exaggerated form in the oldest specimens) of various fishes of the families named. It is a strongly marked sex dimorphic character, which becomes greatly accentuated with age. Aldrovandi's Synagris has been identified as *Dentex vulgaris* Cuv., a fish found in the Mediterranean to-day. Indeed in Fig. 7 is presented a recently figured (1901) head of a gibbous *D. vulgaris* from this sea. Comparison will show how well Aldrovandi's artist "did his job."

This hump commences generally at the level of the eyes and is prolonged posteriorly on the "nape of the neck," sometimes almost to the first dorsal ray (Fig. 7). In some of the parrot-fishes (which have very short jaws) the frontal gibbosity is so far forward and so precipitous that the condition by the inexperienced might be thought a case of round- or pug-head. The form of the hump is very variable (see Figs. 6—in which it is drawn bi-lobed—and 7), but always it gives the fish a very bizarre physiognomy. The gibbosity in both Aldrovandi's and Pellegrin's drawings is a huge affair. Aldrovandi's seems to be bi-lobed, though possibly this is poor drawing; while Pellegrin says that in one specimen the hump measured fully one third the length of the fish.

This body is a sort of fatty tumor found only on males and is best developed in old or possibly senile individuals. Its function is not positively known. One suggested function is that of storage against a time of scarcity. By some it has been compared to the "fat bodies" of amphibians, and thought to supply material for the manufacture of sperms at breeding time. This could be tested by observing gibbous fishes for a diminution of the hump at breeding season in an aquarium. So far as I know this has not been done.

To stout and stolid unimaginative persons of plethoric habit, of whose gray matter one has little opinion, the term "fat-head" is opprobriously applied. I submit that the fishes portrayed in Figs. 6 and 7 have something of this look. If not on this account, then certainly on bearing in mind the composition of this hump, one is perfectly justified in calling these fishes "fat-heads."

Aldrovandi's drawing is certainly the earliest published figure of this abnormality. Belon in his work published in 1554 figures a little fish called *Galerita*, which has on its head a hump which I have viewed with much suspicion. Belon says that "When alive there is on the top of its head a soft erectile crest blue in color." Day, the eminent British ichthyologist, figures and describes a little fish, *Blennius galerita*, with a pair of branched tentacles above and between the eyes. This may be Belon's fish and his figure merely one of bad draughtmanship—but it surely excites considerable suspicion in me.

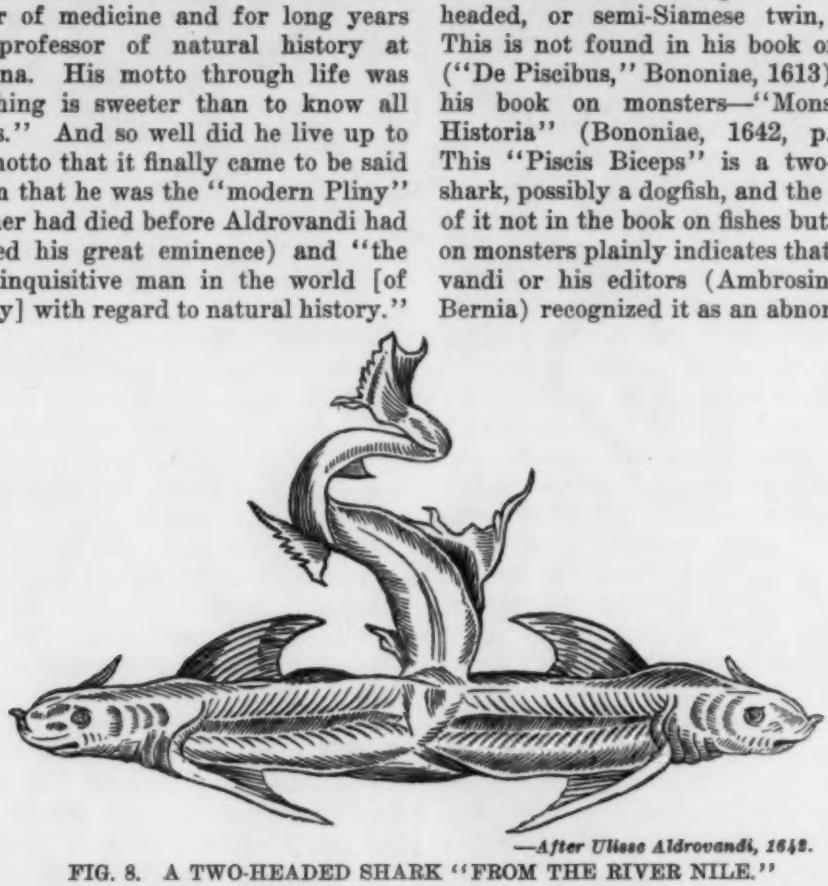
If any reader of this article is interested enough, he might care to see the text and figures of an authoritative article by Dr. Jacques Pellegrin, the well-known ichthyologist of the great Muséum d'Histoire Naturelle in Paris. His "Les Poissons à Gibbosité Frontale" may be found in the *Bulletin de la Société Philomathique de Paris*, 1901 (pp. 81–91, with 5 interesting figures).

Before taking up the figure of the next teratological fish (and the most in-

teresting), which is also by Aldrovandi, it will be of interest to speak briefly of the man. Like the other four he was a doctor of medicine and for long years was professor of natural history at Bologna. His motto through life was "Nothing is sweeter than to know all things." And so well did he live up to this motto that it finally came to be said of him that he was the "modern Pliny" (Gesner had died before Aldrovandi had reached his great eminence) and "the most inquisitive man in the world [of his day] with regard to natural history."

A Two-Headed Shark, 1642

Last on our list but not least in interest is Aldrovandi's figure of a two-headed, or semi-Siamese twin, shark. This is not found in his book on fishes ("De Piscibus," Bononiae, 1613) but in his book on monsters—"Monstrorum Historia" (Bononiae, 1642, p. 428). This "Piscis Biceps" is a two-headed shark, possibly a dogfish, and the placing of it not in the book on fishes but in that on monsters plainly indicates that Aldrovandi or his editors (Ambrosinus and Bernia) recognized it as an abnormality.



—After Ulisse Aldrovandi, 1642.

FIG. 8. A TWO-HEADED SHARK "FROM THE RIVER NILE."

THE FIRST PUBLISHED FIGURE OF A BICEPHALOUS FISH.

All this led to his outlining a plan of a brobdingnagian encyclopedia of natural history. To this and to his museum he gave his fortune and all the long years of his life. His "Opera" comprise 13 great folio tomes. Five or six were published before his death in 1605 or 1607, the others were brought out later by his associates, pupils and friends. These works like Gesner's contain practically all natural history from Aristotle down to his day. They are source books of enormous value. Much of the materials (drawings, etc.) of his books and museum are still to be found at Bologna and elsewhere in northern Italy.

To Aldrovandi's museum in Bologna came animal curiosities from all over the world, and among them the "Piscis Biceps." This our old natural history book states was caught "in the River Nile in Egypt not far from the town called Latislana." There is much discrepancy here. Sharks are marine fishes and the Nile is fresh water. This double-head might have been taken in one of the Nile delta distributaries if this were brackish. But the tides at Alexandria rise but a few inches and the volume of the Nile is great. As to the town Latislana, the only one I can find trace of is or was in Italy.

Another doubtful thing is that this dicephalous shark was "almost equal in size to a crocodile." If so, it must have been a very small "crocodile on the bank of the Nile." Two-headed shark embryos are sometimes found, but after hatching their swimming is so impeded that they are quickly devoured—by voracious fishes, including sharks, and possibly their own hungry parents. But whether the specimen was large or small, it is a two-headed shark, the oldest ever figured, and so far as I know the only one figured until about 1824—182 years later.

Like Gesner's artist, who took great liberties in drawing his round-headed carp, so Aldrovandi's painter likewise let his imagination run away with him. He has surely exaggerated his specimen. He had drawn this shark in the shape of a T—each head standing out at right angles to the trunk. All the double-headed shark embryos in the figures I have seen and all two-headed fish of any kind which I have examined are Y-shaped. Aldrovandi's unknown artist may have had a T-headed specimen, but like my Scotch ancestors I "hae me doots."

The explanation of the origin of two-headed animals is a very obscure and complicated one. It is most easily observed and studied in fish eggs in hatcheries. But even in the study of such eggs much controversy has raged. Hence it does not seem wise to lumber up a popular article with obscure technicalities.

It may be of interest to state here that the library of the American Museum is the fortunate possessor of every one of the works referred to herein, and that it also has all the natural history works of each author—*in first editions* and also in versions in other languages and in later editions. Some of these books are so rare that they are literally "worth their weight in gold."

It is interesting also to note that four out of the five early naturalists in the earliest books on fishes figured and after some sort of fashion described abnormal fishes. That they did not know that they were abnormal (except in the case of the two-headed shark) is not to be charged against them, for their figures of these fishes are before us. Without knowing it, they started the science of teratology of fishes, and it is their due that credit should be given them.

Just here the reader must understand that such adult abnormal fishes are relatively exceedingly scarce even in these days when vast catches of fishes are made. Witness the relatively few forms that have been figured and described by scientific men. Witness also my own case—the few that have come to me during the past ten years when friends—anglers and commercial fishermen—have been on the watch-out for these for me, all along our north Atlantic coast.

There are several reasons for this. Although relatively considerable numbers of teratological fishlets are hatched, most die in babyhood (if one may speak of such for fishes) too handicapped to withstand the ordeal of development. Because their physical deformities handicap their movements, most of those that grow to be fingerlings are readily snapped up by marauding voracious fishes. This high mortality allows but few to come to maturity, and these few escape the angler generally and in commercial catches in nets are lost in the multitude of entirely normal fish. More credit then to these old ichthyologists that in the very beginning they picked out, as did Belon first of all (in 1553), fishes "of an extraordinary kind."

SOME EFFECTS OF ANIMALS ON PLANTS

By Dr. WALTER P. TAYLOR

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IT is recognized that all animals depend, in final analysis, on plants. It is coming to be more widely appreciated also that plants in turn depend on animals to a very considerable extent; that process and practice in farming, and especially in wildlife administration, range management and forestry, must increasingly take this reverse dependence into account if well-rounded and satisfactory results are to be obtained.

It is particularly desirable that these animal relationships to plants be known and applied as adequately as possible in the extensive national program of reforestation, range rehabilitation, erosion control and natural resource conservation now going forward. We should try to anticipate difficulties from animals likely under certain conditions to be inimical to seeds and seedlings, whether of range plants or forest trees; and we ought to take full advantage of those animals that may be counted on to assist in these colossal enterprises for the restoration of our exploited areas. The need is not for "total protection" of so-called "beneficial" species, nor for "eradication" of "pests" but for scientific management of all wildlife, in accordance with an enlightened understanding of what Allee has called the geo-bio-ecology of each locality.

In this paper the writer makes an attempt to explore some phases of the relationships involved.

(1) GRASS EATING

A very practical aspect of the influence of animals on plants is their work on forage on the open grazing range. Problems involved affect no less than 1,055,000,000 acres of land in the United States, or 55 per cent. of the total area of the country. It has been estimated that grassland occupies 13,000,000 of the 52,000,000 square miles of land surface of the globe. It is not impossible, as one writer states, that "Human life has been and is more dependent upon grasses than upon any other group of living beings." The conservation and proper maintenance of these vast and valuable grassland areas are of vital importance probably to a majority of the world's population.

Under original conditions all forms of life were components of an organic-inorganic unity fluctuating rather widely but continuing to function successfully and practically in balance over long periods of time. Under the aegis of man's supremacy, however, natural equilibria have been disturbed. Through artificial and abnormal processes, among them grazing, fire, elimination of native species, introduction of exotics, cultivation, fertilization, irrigation, drainage, game preservation and some other processes, the original balance is upset. It is safe to say that all inhabited portions of the earth have been modified. The new conditions favor some wild species, eliminate others. Some of the results: Temporary vastly enhanced productiveness of land through agriculture (considered broadly to include not only farming but wildlife management, range administration and forestry); accelerated erosion, both by water and by wind; shrinking water supplies for domestic use and irrigation; forest, range and wildlife depletion; and soil exhaustion.

New problems arise in almost exact proportion to the disturbance and interruption of original conditions. Certain

species of birds, rodents, lagomorphs, ungulates, insects and other animal forms, previously kept in bounds by an adequate environmental resistance, now become positively inimical to man's interest. Others become highly useful. Some are beneficial at certain times and places, harmful at others. No hard-and-fast catalog of "good" and "bad" species can be made. The entire biological spectrum is altered and study of the bioecology of the grassland community becomes the most important activity in which man can engage on the plains, prairies and savannas of the world.

(2) Overgrazing

The evil effects of overgrazing have been commented on since the dawn of history. In our own country as early as 1872 a report of the United States Department of Agriculture pointed out that native grasses were disappearing from the prairies of Texas, especially on bottomlands, "depasturing" of cattle being destructive to them.

E. D. Ball estimates that insects, including leaf-hoppers, grass-hoppers and others, cut down the available forage —principally grass—on the best ranges in the vicinity of Tucson, Arizona, by 20 to 30 per cent.

Our own investigations have dealt with the lagomorphs and rodents, principally in Arizona. Results of sample plot clipping studies made by McGinnies and the writer on the Santa Rita Experimental Range showed that the antelope jack rabbit (*Lepus alleni*), the banner-tailed kangaroo rat (*Dipodomys spectabilis*) and certain small species of lesser importance consumed or accounted for 28.7 per cent. of the total vegetation and 38.8 per cent. of the total valuable forage grasses. It was found that grass constituted 24.1 per cent. of the food of the Arizona jack rabbit (*Lepus californicus arizonae*) and 45.0 per cent. of that of the antelope jack rabbit for the year. Four-years sample plot tests at Coconino, near Grand Canyon, Arizona, showed that, under the conditions of the experiment, prairie dogs consumed 69 per cent. of the wheat grass (*Agropyron smithii*) and 99 per cent. of the sand dropseed (*Sporobolus cryptandrus*), or 80 per cent. of the total potential annual production of forage. Results of a one-year experiment at Williams, Arizona, showed prairie dogs accounted for 83 per cent. of the blue grama (*Bouteloua gracilis*).

Admittedly these plot studies are highly incomplete and partial. So many factors are involved that the results must not be pushed too far. But they do afford a quantitative suggestion of the potential work of certain rodents and lagomorphs under particular conditions.

It is perfectly obvious that the work of grazing animals may profoundly affect the vegetation cover. Clements is authority for the statement that the general apparent replacement of tall grasses (of the type of *Andropogon* and *Stipa*) by short grasses (like *Bouteloua* and *Bulbilis*) in the mixed prairie regions of central Nebraska, Kansas and elsewhere in that region is explained by the effect of grazing. The buffalo is assumed to be the original agent responsible for the elimination of the tall grasses and their replacement by buffalo grass — appropriately named ! — while domestic live stock in more recent days continued and accentuated the trend toward short grasses.

Ground squirrels are destructive to forage grasses in many localities. Thus Grinnell and Dixon estimate that 750 Oregon ground squirrels during the growing season of pasture grass eat as much as one steer. It is further estimated that the population of California ground squirrels (*Citellus beecheyi beecheyi*) takes the place (in that state) of 160,000 cattle or 1,600,000 sheep. A part of their green feed is grass. In Arizona it has been estimated, on the basis of cage food tests, that on the aver-

age 15 antelope jack rabbits will eat as much good forage, chiefly grass, as a sheep, and 74 as much as one cow; while of the smaller Arizona jack rabbit, 30 will eat as much as one sheep and 148 as much as one cow.

Kashkarov and Kurbatov noted the part played in the Kara-Kum Desert in middle Asia by long-toothed ground squirrels (*Spermophilopsis leptodactylus*). These rodents dig up the sand to procure the bulbs of *Poa bulbosa*, their main food. The number of holes aggregate 13,135 per hectare. Where *Poa bulbosa* is absent, the squirrel feeds on the roots of *Aristida pennata*. The sand is loosened and begins to move. "Then the rodents migrate to another place." The assumption is that these activities appreciably reduce the carrying capacity and promote the drying of the desert. Seemingly in Russia as elsewhere ". . . man and his domestic animals are responsible for the formation of the worst kind of desert." The relationship to rodent damage of overgrazing by the camels, sheep and goats brought in by man has not been worked out. In arid areas of the southwestern United States, we find that, in many places, as overgrazing becomes apparent, some rodent depredations tend to become more serious.

Hill, of the National Forest Service, believes that in the vicinity of Tucson, Arizona, heavy grazing by domestic live stock, noticeably accentuated in recent years by native forage-feeding species, as the kangaroo rat and jack rabbit, was doubtless the greatest contributing factor in the change from a short grass and browse type to a vegetation characterized by less palatable and hardier desert plants.

Too much emphasis can hardly be given to considerations of grazing by domestic live stock. The stocking of our ranges with millions of cattle, horses, sheep and goats has had and is having a profound effect not only on the grasses but on all forms of vegetation and all animal life in the biotic communities affected. The question still presses for answer: How many domestic live stock can be supported on a given area without deterioration of the forage resource and the soil? Scientists, range users, owners, entire communities, are vitally interested. Doubts have even been expressed regarding the adequacy of an economic system which places chief emphasis on private profits without regard for the future productivity of the resources utilized (see, for example, the discussion of the responsibility of foresters by Silcox).[1]

Another question may often become pertinent: "To what extent is it economically feasible to control the rabbits, rodents and insects which often become troublesome feeders on native grasses?" In some localities the answer is obvious with little preliminary study. In others the value of the resources at stake, the ability or willingness of the government or the private land-owner to cooperate by reducing domestic stock so the grass will have a chance to recover following the control operation, the present degree of injury to vegetation and soil and the proper use of the land from the standpoint of highest long-time use to the greatest number of people, all should be given consideration. Seeming overproduction, so troublesome at present (1936), emphasizes the undesirability of attempting to graze submarginal lands which should be left for upland game.

The further query arises whether any live stock grazing at all on some lands is not overgrazing. While wild grazing animals, such as the bison, pronghorned antelope, elk and some of the smaller forage-feeding species were in former times balanced, on the average, with the vegetation, it appears that on certain submarginal lands, at present, any increased pressure at all is too much. In such cases it is coming to be realized that funds spent for range rehabilitation,

[1] *Jour. Forestry*, 33: 198–204, 1935.

whether for seeding or planting, rodent control, weed control or erosion control, are likely to be in vain. An inviting alternative, in these cases, is to leave the land alone, let nature heal herself. In some localities game will come back, or can be restocked to advantage. Substantial values from native wildlife, watershed, recreation and scientific uses can be assured. The land can be turned into an asset instead of a liability.

The Biological Survey has shown that many animals, both birds and mammals, regularly prey on grass feeders. The work of insectivorous birds is very well known, but insectivorous mammals have been largely overlooked. The grasshopper mice, for example, consume 88 per cent. of animal food, chiefly insects. Coyotes, foxes, badgers and skunks feed extensively on rodents and insects. Much rodent damage is directly proportional, within limits, to artificial range disturbance. Evidence is accumulating also that if grazing use is conservative, the range user will have far less trouble with weeds, insects and rodent pests than if he permits over-heavy use.

In this connection one should note that the so-called predatory and rapacious species, including such creatures, for example, as the coyote, bobcat, mountain lion and fox, are practically always favorable to plant growth, in that they help to keep down the number of forage-feeders, and doubtless sometimes prevent the occurrence of irruptions of rodents or other species which might otherwise occur.

Some rodents and insects seem to appear in increased numbers along with the weeds which become more numerous on overgrazed areas. On certain areas with which the writer is familiar the pressure of live stock is so great that overgrazing would have occurred regardless of the work of rodents. This is an important point in range management; for it will do very little good to control forage-feeding rodents if live-stock pressure is so heavy that overgrazing will take place anyway.

The seriousness of overgrazing is being increasingly recognized by all intelligent stockmen, who are insisting on the closer and more careful regulation of grazing use in the interest of the future of the industry. This point is clearly indicated by the enactment of federal legislation, such as the Taylor Grazing Act, having for its object the regulation of grazing on the public domain.

It is recognized that grazing is a normal process, without which, as a usual thing, the grasses and forage plants do not always prosper. Very old areas under total protection often deteriorate. While the causes of this tendency to go backward are not well known, it appears that the accumulation of dead stems and leaves, normally removed by grazing, handicaps the growing plant. Under original conditions the grazing use of our ranges by game and rodents was well adjusted to the maintenance of the vegetation.

It is unreasonable to expect that plants can withstand all the original pressure from the wildlife and a tremendous weight of domestic live stock, in addition, without serious and in some instances rapid deterioration.

On the other hand, on primitive or wilderness areas, where live stock is excluded, seemingly the aim should be to retain the native game and forage-feeding rodents, *for the best interest of the plants.* It is, of course, highly desirable also to keep a normal population of flesh-eaters, so the forage-feeding species of game and rodents will not become overabundant.

(3) Eating Stems, Roots, Barks, Buds and Leaves

In certain localities animals that consume the bark, buds, leaves, seeds and

roots of forest trees undoubtedly tend to favor the extension of grazing range at the expense of forest. The principal wild offenders are beetles and other insects, rabbits, hares, squirrels, porcupines, wood rats, mice, deer and other game species.

Between 1895 and 1905 a certain bark beetle destroyed a billion feet of timber in the Black Hills, and from 1918 to 1925 about 300,000,000 board feet on the Kaibab.

Porcupines work on forest seedlings and older trees, too; wood rats, in places, on natural reproduction of the forests. A lepidopteran larva was found in the Argentine that attacks the prickly pear. Imported into Australia, it has to a considerable extent brought this plant, a single species of which had become a serious pest over about 50,000,000 acres, under control.

Bark feeders include at least the following mammals: meadow mice, pine mice, pocket gophers, rabbits, hares, mountain beavers, wood rats, woodchucks, porcupines and beavers. Mention might well be made of a number of other squirrels, in addition to the woodchuck—and of the elk also, which sometimes feed extensively on aspen bark.

Rabbits are well known to exercise considerable effect on the vegetation—and so on all the organisms associated with it.

For hundreds of years surpluses of game have been recognized as exercising an appreciable effect on plant associations. In 1789 the French *Tiers Etat* made the assertion that the most terrible scourge of agriculture is the abundance of wild game. Overstocking with deer has been assigned as one of the causes of alteration of plant associations in England.

Some of our own experiences in America have emphasized the dangers of game surplus in no uncertain terms. Overpopulation of deer has developed on a number of the desert ranges and forested areas of the southwestern United States, and similar difficulties have arisen in Pennsylvania and other eastern states.

The situation on the Kaibab National Forest in northern Arizona has rightly been given a good deal of attention. The trouble seems to have been initiated in 1905, when President Theodore Roosevelt set aside a large portion of the Kaibab country for a game preserve. In the early days considerable numbers of cattle, sheep and horses grazed on the area, and numerous Navajo Indians hunted deer (*Odocoileus hemionus*) thereon for food. Also present in the region was an abundance of mountain lions and coyotes, natural enemies of the deer. The institution of the game preserve radically changed the status of the area. Grazing by live stock was reduced. The Indians were prevented from hunting. Flesh-eating mammals were restricted in numbers. Relieved from natural controls and unharvested by man, the deer population expanded from perhaps 3,000 or 4,000 originally present to a maximum estimated all the way from 25,000 to 100,000. Forest Service officials and others, including the writer, were impressed with the alterations taking place in the vegetation. In 1931 the Kaibab Investigative Committee concluded that the Kaibab was not producing more than 10 per cent. of the available and nutritious forage that it once did, and that if deer overgrazing continued the aspen-forest type would ultimately disappear from the Kaibab Plateau. The writer and others who have independently studied the problem were of much the same opinion.

It is probably not an accident that pretty nearly all the difficulties encountered in over-browsing by deer and other animals have arisen in connection with disturbances of one sort or another by man.

(4) Consuming, Disseminating and Storing Seeds

Probably few more important animal influences exist than those in relation to the seeds of plants.

Insects attack the seeds of various trees and other plants; tree squirrels, chipmunks, and at times other rodents, store and consume quantities of conifer seeds and sometimes cut off cones; mice of different species are avid consumers of the seeds of forest trees and of certain grasses of plain and desert; birds consume quantities of seeds.

Cage experiments conducted by the writer at Fort Valley, Flagstaff, Arizona, disclosed that the gray-collared chipmunk (*Eutamias cinereicollis cinereicollis*) will eat an average of 277 seeds of the ponderosa pine in each 24-hour period. An Arizona mantled ground squirrel (*Callospermophilus lateralis arizonensis*) under similar conditions will consume 338 pine seeds in a day. The minimum seed supply necessary to stock an area completely in one year under favorable climatic conditions has been estimated as eight pounds per acre, or 114,400 seeds. Four chipmunks and two mantled ground squirrels could eat the entire eight pounds in 64 days.

Plot experiments at Fort Valley have shown a marked effect on planted ponderosa pine seeds by birds (long-crested jay, red-shafted flicker) and probably also by certain mammals, especially the Arizona mantled ground squirrel, gray-collared chipmunk and tawny deer mouse. In a small plot open to birds and rodents 78 seedlings appeared; in a similar plot adjoining, protected from these species, 269 seedlings grew.

In 1928 G. A. Pearson and B. R. Lexen, of the Forest Service, in cooperation with Dr. Frederic E. Clements, of the Carnegie Institution, and the writer, initiated a test at Flagstaff, Arizona, to determine the influence of bunch grass on germination of ponderosa pine. This experiment has been reported on recently by Pearson.[2] The findings strongly emphasize the important rôle played by field mice (*Microtus mogollonensis*) in the yellow pine type of northern Arizona, where grass cover becomes heavy. Pearson's Table 1 shows some striking differences in the number of seedlings in the plots under protection from rodents as compared with those unprotected. On August 22, 1929, 1,781 seedlings were counted on the protected plots, 618 on the unprotected ones. On August 18, 1933, 100 seedlings had survived on the protected plots, 3 on the unprotected ones. As Pearson points out, rodents were abnormally abundant here as a result of protection of the grassy cover from grazing. Predatory enemies of the mice had also been reduced.

A number of writers have emphasized the difficulties associated with reforestation efforts as a result of the work of rodents. Clements concluded that the real importance of fire in the lodgepole pine forest lay in its removal of rodents for several years.

Observations in California, Michigan and elsewhere indicate a radical difference in rate of rodent reinvasion following fires in different localities. That size of seed is significant in relation to rodent damage was shown by a Canadian investigator, who pointed out that greater success was obtained in New Brunswick by using the small-seeded white spruce rather than the larger seeded white pine. More recently the same point has been emphasized by a number of Forest Service workers. These investigations are of unusual interest and potential value in connection with the emergency conservation work in reforestation now going forward under governmental auspices. All available data must be carefully taken into account, and additional information gathered, if the reforestation program is to succeed. Nor is the case always so simple as might

[2] *Jour. Forestry*, 32: 545–555, 1934.

perhaps be indicated by Pearson (*loc. cit.*), who recommends poisoning of small rodents through the summer and early autumn of a year of pine seed development. For many questions arise: What rodents are involved? Is rodent control on this particular area economically feasible? What species should be controlled? Over how large an area should control operations be conducted? What precautions should be observed to protect innocent or valuable wildlife? Like the problems of vegetation, those of animal life are extremely complicated. A good deal of additional study is needed. In every case a qualified wildlife research specialist should be called on for an opinion prior to the initiation of control operations.

Over considerable areas in northern Arizona live-stock grazing, especially grazing by sheep and goats, often supplemented by forage-feeding rodents, is bringing about the spread of junipers at the expense of the valuable grama grass cover. The grass is removed or weakened by grazing; the juniper seed passes through the alimentary tract of the sheep or goat and easily becomes established in grazed areas. In this case, contrary to that cited on a previous page, the forest (woodland) is being extended through biotic influence at the expense of grass cover. If the process continues long enough considerable areas of grass will be altogether lost to grazing.

A similar tendency for mesquite to "take over" grassland is strongly developed in certain areas in southern Arizona, for example, in the Empire Ranch country and on the Santa Rita Experimental Range. The influence of live stock and range rodents is apparently brought to bear in this case also. Cholla cactus, likewise, is spreading in southern Arizona. Cattle distribute the joints, wood rats often drop them en route to their dens, and these activities, associated with lessened grass competition resulting from heavy grazing, facilitate the spread of the cholla. Seemingly the most important component of this animal influence is live-stock pressure. In its absence the rodents would make little difference, one way or the other. Oaks and junipers are spreading in the hill country of Texas. It is probable that protection from fire and heavy grazing by live stock are the principal factors involved.

The writer does not want to leave the impression that the work of the native birds and animals in relation to seeding is all bad. Many years ago Barrows[3] called attention to the fact that for centuries birds have been recognized as one of the agencies in forest rotation and in resurfacing with vegetation tracts swept bare by wind, water, fire or man. The fruit and berry eaters function most effectively. Forbush has pointed out that birds destroy the fruit but plant the seed, being instrumental in extending the woodlands and thickets in which they dwell. McAtee, in a letter to the writer, points out that the crow, starling, waxwing, thrush, catbird and mockingbird are among the species that eject seeds from the mouth. He writes this is a trait of highly frugivorous species and of insectivorous species as well at periods when they resort to a fruit diet. "In the long run, the process undoubtedly is important among the means by which fruit-bearing plants are distributed."

Rodents assist in forest maintenance through caching of crops of Douglas fir seed in the surface soil, distributing black walnut and other nut-bearing species of oaks, hickories, etc., and planting western yellow pine in Montana, Idaho and Oregon. The red squirrel is a replanter of the hardwoods, and one observer has expressed the opinion that its service as a forester far outweighs the little harm it does.

Any one who has traveled in the area and given some attention to the matter must realize that the pine squirrel has a

[3] Rept. Chief Div. Ornith. and Mamm. 1890, 1891: 280–285.

far-reaching influence on the trees in the Canadian Zone forests of the mountains of the West. In the fall it stores great numbers of pine cones and pine seeds, so that collecting from seed hoards is a recognized method of securing seed for planting. One Forest Service worker asserts that the caches of small red squirrels average about two bushels, but not uncommonly reach 8 to 12 bushels of cones; and there are reports of up to 40 bushels of western white pine cones having been found stored in a single spot, presumably by one squirrel. It must often happen that seeds are planted by this instrumentality. It is scarcely to be doubted that these squirrels, although they eat the seeds, are important in the maintenance of the forests in which they dwell. Finally McAtee, of the Biological Survey, asserts definitely that birds are indispensable agents in the natural dissemination of trees which reproduce themselves by fleshy fruits and nuts and that they aid also in reseeding coniferous trees. It should be remembered that detrimental animal effects are easy to see, while beneficial effects have to be carefully worked out through research. Most of our "practical" treatment of these problems is based on superficial observation. As soon as we can we ought to complete our studies of all these things scientifically through well-planned, well-financed and well-manned research.

In crossing the state of Texas in September, 1927, Clements, Tharp and the writer were impressed with the obvious importance of mammals and birds in relation to distribution of vegetation. One would like to know the precise vegetational history of the region. Western elements, including the mesquite, palo verde, prickly pear and snakeweed, were noted just after crossing the Brazos River, well in the eastern third of the state. Apparently the clearing of the oak-hickory woods was a first step in the far eastward spread of these western species. The influence of animals must also have been considerable. The buffalo may have helped to seed up some of the clearings with mesquite. Assuredly the introduction of Spanish horses and cattle accelerated the process. Overgrazing, to which many areas have been subjected, has assisted the spread of western scrub, through the wide-spread breaking up of the grass cover, consequent reduction in grass competition and easy establishment of scrub seedlings.

Very much in evidence, particularly through central Texas, was the frequent limitation of young shrubs to a circle over the ground surface dominated by the crowns of trees, in this case mesquites and oaks. The evidence indicated that the seeds had been planted by birds using the mesquites or oaks as perching places. An incomplete list of these bird-disseminated plants included *Zizyphus* sp., *Condalia* sp., *Lycium* sp., mesquite, wild grape, *Smilax bona-nox, Celtis reticulata, Berberis* sp., *Rhus trilobata, R. virens, R. lanceolata, R. toxicodendron, Xanthoxylum* sp., *Adelia* sp. and *Koeberlinia* sp. All of them, it will be observed, are suitable for bird food.

Over vast areas in western Texas are to be found mesquite savanna and desert plains. This type of semi-arid land prevails from approximately Odessa, Texas, through New Mexico to about Sentinel, Arizona, where it gives way to extreme desert. It is becoming clearer that in some places over this great area, perhaps over most of it, grazing animals, supplemented by forage-feeding rodents and rabbits, have tended to suppress the grasses and disseminate scrub. Birds and certain mammals have helped to spread the shrubby species. Relicts show unmistakably that in places, at least, grassy desert plains formerly prevailed where now the relatively worthless semi-desert holds sway. Apparently a similar deterioration is taking place in other localities over the earth's surface. For example, in speaking of the Kara-Kum Desert region, the alert Russian inves-

tigators, Kashkarov and Kurbatov,[4] have rather pathetically remarked, "The northern Tertiary plateau is slowly changing into a sand desert." Responsibility for the steady encroachment of desert in these various cases seems to belong to man and his grazing animals rather than to the native wildlife.

(5) Fertilization

The innumerable and complex adaptations by means of which flowers secure cross-pollination through the agency of insects are among the most marvelous phenomena known to the biologist. While some plants are adapted for cross-pollination ". . . by wind and water, the majority of flowering plants exhibit profound modifications of floral structure for compelling insects (and a few other animals, as birds or snails) to carry pollen from one flower to another." Evidently the dependence of flowers on insects, on certain birds and on a few other animals, is so great that they have, in a manner of speaking, gone to extraordinary lengths to acquire the necessary adaptations to benefit from the visits of these pollinators.

The pollinating functions of bees and moths are pretty well understood. Birds as pollinators are less well known. Ornithophilous flowers include a considerable variety of plants, principally in the tropics. Among genera which are in part at least bird-pollinated are *Marcgravia, Norantea, Poinciana, Strelitzia, Protea, Feijoa* and *Erythrina*. Birds involved include principally hummingbirds, sun-birds and honeysuckers. One worker considers birds to be by far the most important agents in the pollination of flowers in Western Australia. He thinks they are the chief if not the only efficient pollinators of the genus *Eucalyptus*. The bird-pollinated flowers of *Erythrina variegata*, common along the Java coast, are visited by 26 different birds, as well as by squirrels!

[4] *Ecology*, 11: 35–60, 1930.

(6) Summary of Effects of Animals on Plants

One should not permit the animal difficulties which so often result from disturbance of an area by man to blind him to the fact that animals make numerous and necessary contributions to plants. Adams once said the relations of game to forest constitute a permanent and not a temporary alliance. We can go further and say that the relations of animals to plants and both to their mutual environment constitute a permanent and not a temporary alliance, everywhere that normal community relationships exist.

It is easy to see the dependence of flowering plants on the animals that pollinate them. Less easy to visualize perhaps, but possibly even more important, are the numerous other relationships in which the welfare of the plant population is dependent on animals.

Animals assuredly could not live without plants—but plants probably could not, except in artificial environments, live without animals.

The following suggestions (not in the order of their importance) indicate, in a somewhat sketchy way, some phases of the relations of animals to plants in a terrestrial environment. It should be noted that the extent, the quantitative significance and the important details of these relationships, remain, in most cases, to be worked out.

(1) While under original conditions native animals were in balance with vegetation, disturbances of various kinds by man, such as grazing by domestic stock, fires, lumbering, cultivation, etc., have altered the status of the original resident species. The equation in every disturbed locality is a new one, requiring for its solution careful consideration of local as well as general factors.

(2) Grass consumption by insects and vertebrates is considerable, and in some instances serious.

(3) Eating by animals of the stems, roots, barks, buds and leaves of plants is also significant. The work of bark beetles, of herbivorous rodents, of rabbits and of certain game species is sometimes spectacular and of no small moment in certain localities.

(4) The ingestion, transportation, storage and involuntary planting of seeds is of enormous significance, sometimes detrimental to man's interest, probably in most cases beneficial.

(5) It is impracticable and undesirable to classify wild species of animals as "bad" or "good." The number of individuals of the species in question, surrounding conditions, time and place, make so much difference that each problem, whether of conservation or control, should be considered by itself and by a group of competent workers, including specialists in the wildlife field.

(6) Animals depend, in final analysis, on plants, but plants also depend to a considerable extent on animals.

(a) Plants must depend to a considerable extent on protozoa, crustacea, worms, insects and vertebrates to help form, fertilize and cultivate the natural soil so that it will be a suitable substratum for their growth.

(b) Flowering plants depend on fertilization by animals for their continued existence.

(c) Forest trees depend to a considerable extent on those animals which help to plant their seed and spread them. Forest rotation and reforestation are often carried forward by the seed-eating animals.

(d) Brushy and herbaceous plants depend to a considerable extent on birds and other animals for their dissemination. Revegetation is often largely dependent on these animals.

(e) Nearly all plants depend to a certain extent on animals (flesh-eaters, birds, insects) for protection from other animals (chiefly insects and rodents) which attack the bark or other parts of the plant.

(f) Plants sometimes owe their persistence to some extremely injurious animal influence, which benefits them because it injures their competitors slightly more. Dwarf grass-heath, in East Anglia, has been cited in illustration of this.

(g) Plants may depend on animals for a part of the carbon dioxide they breathe.

(h) A few plants depend on animals for a part of their food. Examples, the Sundew, the Venus's flytrap, etc.

(i) Marsh plants and meadow plants and later plants of dry environments often depend on the beaver for the natural "reclamation project" of which they are beneficiaries.

(j) Some plants, particularly grasses, depend on animals for the removal of surplus parts, dry stalks, etc. Moderate natural grazing releases the plants and permits them to grow more strongly than would otherwise be the case.

(k) Plants depend to a certain extent on herbivorous animals for assistance in keeping their own plant numbers down so that unwieldy surpluses and disastrous over-population are prevented.

(7) The present day nation-wide operations of the federal and state governments in reforestation, erosion control, recreational development and range rehabilitation emphasize more than anything that has ever happened in American history the need for more adequate knowledge of the interdependence of animals and plants and their relations to their environment. Liberal investment in geo-bio-ecological research would doubtless help prevent losses and would be sure to return big dividends in more successful conservation.

JAMES WATT: A SCIENTIST RATHER THAN AN INVENTOR

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IT is generally thought, even by many engineers, that James Watt originated or invented the steam-engine. This is far from true; what Watt really did was to develop a slow-working, cumbersome steam pump, excessively wasteful of fuel, into a quick-working, powerful and efficient steam-engine and finally left it virtually as it is to-day. The writers propose to show that this development by Watt was the result of a most careful, thorough and scientific research involving the properties as well as the economical use of steam.

The use of steam for power purposes, however, dates much farther back than the period when Watt lived. The elastic power of water vapor must have been familiar to man from the earliest periods of our history. The first recorded observation of the application of steam appears to have been made about one hundred and thirty years before the Christian era by Hero,[1] the Elder. No other mention of steam as a prime mover occurs in the works of ancient authors, nor among more modern writers until about the year 1563, when Mathesius[2] hints at the possibility of constructing an apparatus, similar in its operation and properties to those of the modern steam-engine. Many men who made improvements either in its construction or application have been credited with the invention of the steam-engine. The result of the best of these improvements was embodied in the Savery engine of 1699. The Savery engine was a pumping engine, essentially the same as the simple injector of to-day. The limits of the engine and the inventors' hopes for it may be expressed by a quotation from Savery: "For," he says, "I will raise you water 500 or a 1000 feet high, could you find us a way to procure strength enough for such an immense weight as a pillar of water of that height; but my engine at 60, 70, or 80 feet, raises a full bore of water with much ease."

The next important development was that made by Newcomen, who, in 1705, developed an atmospheric engine containing a piston. The use of atmospheric pressure as the motive power necessarily resulted in a large engine (see Fig. 1). The Newcomen engine aroused a controversy, because it infringed on Savery's patent. This atmospheric engine was improved in various details by many eminent men, being finally brought to its apex by Smeaton in 1772. In spite of these improvements it was a more expensive form of power than that of horses, because it used large quantities of fuel and steam. These engines were so wasteful that they used about one half of the steam that was generated for them, to warm up the cylinder and piston on each stroke. It was the realization that such a condition was not only extremely wasteful but unnecessary that prompted James Watt to make a thorough study of the steam-engine.

After complete research and experimental consideration of steam and the existing forms of steam-engines, Watt wrote the specifications for a new design radically different and of such superior economy that it deserves lasting recognition. The history of mechanical engineering can furnish no other example of so great an improvement having been

[1] "Pneumatica"—Hero.
[2] "Sarepta"—Mathesius.

achieved by a single individual. Watt's developments were the progeny of his own fertile brain, and were brought to perfection by his own sagacity and perseverance. Before relating the steps which he took in the creation of his marvelous achievement, it is desirable to review his personal history.

James Watt was born in Greenock, Scotland, on January 19, 1736. From boyhood he suffered ill health and at an early age he displayed a superior genius for mechanics. After spending three years in apprenticeship as a mathematical-instrument maker in London, he returned to Glasgow where he was later employed at the University of Glasgow as a mathematical-instrument maker. Watt read extensively and studied quite thoroughly metaphysics, chemistry, architecture and most of the modern languages. He was well liked and associated with the most eminent men of that time in Scotland and England. As a result of such self-education he was a man of true philosophical mind and conversant with all branches of science.

It was while at the university that his research and experimenting with steam really began. It is said that his attention was turned to the powers of steam in 1759, when Dr. Robinson of the university proposed to him some ideas relative to wheel carriages. However, nothing developed concerning such an apparatus. Up to this time Watt was not familiar with steam nor the steam-engine, as he had confined most of his time to the making of mathematical instruments.

There is evidence which proves that Watt was a man of unusual ability and was, therefore, ably fitted to cope with involved problems beyond the field of his immediate interest. For instance, after repairing a model of the Newcomen engine in 1763, his natural activity of mind rendered this model a subject of profound meditation, and led him into a course of practical inquiry respecting it. He found that most of the trouble in this engine was due to the fact that too much of the heat in the steam was lost by heating the cylinder. This loss he found could not be eliminated in the engine in its original state, since it was necessary to cool the cylinder in order to condense the steam. Watt realized the difference in conductivity and heat capacity be-

FIG. 1. ATMOSPHERIC ENGINE
FROM "THE STEAM ENGINE," BY D. LARDNER. 1840.

tween wood and cast iron, so he tried to overcome this disadvantage by building an engine with a wooden cylinder. This idea was soon abandoned, but it did have its compensation, as it led him to study the properties of steam, as to pressure, temperature, elasticity, weight, concealed heat, etc.[3]

Here again we have another instance of Watt's very active philosophical research that terminated in an important practical result, for he found that at

[3] For further discussion as to the methods Watt used, see "Treatise on the Steam Engine," by Farey, pages 311 to 313.

atmospheric pressure a pound of steam contains 960 heat units. This was indeed a large quantity, and therefore he thought that the economical use of the steam should be the guiding factor in engine design, rather than the boiler and furnace, which had been the main objectives in former designs. This information allowed Watt to reach this all-important conclusion to make the best use of the steam—the steam cylinder must be kept as warm as possible and condensing the steam must be done outside of the cylinder. He did not make use of this, his great idea, until 1765, when he conceived the idea of a condenser separate from the cylinder. This indeed, as we know now, was marvelous reasoning, but he did have difficulty, namely, how was he to get rid of the air and injection water? This latter problem apparently did not worry Watt a great deal. The method he intended to use to overcome this difficulty can be seen in the words of part of his first patent of January 5, 1769:

> Firstly, that vessels in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire engines, and which I call the steam-vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it.
>
> Secondly, in engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessels or cylinders, although occasionally communicating with them. These vessels I call condensers.
>
> Thirdly, whatever air, or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels, or condensers by means of pumps.
>
> Fourthly, I intend, in many cases to use the expansion force of the steam to press on the pistons, in the same manner as the pressure of the atmosphere is now employed.

From these statements one can see that Watt's chief interest was economy and that he was obliged to state the properties of a machine that had never been built. Although he knew the merits and truth of his deductions, he did not know how he was to execute them in the form of an actual engine. His patent does not describe a machine, but merely states methods for decreasing the engine's steam consumption.

About the time Watt obtained his patent, he became associated with Dr. Roebuck, who had started the Carron iron works in Scotland. They proposed to start manufacturing engines extensively under the patent. Watt started his first real engine, which had a cylinder diameter of 18 inches, at Kinneal-house. This was an experimental engine, and was, therefore, altered and improved from time to time before it was finished. The greatest difficulty in the construction of this engine occurred in the boring of the cylinder and in the packing of the piston to make it steam-tight.

While Watt was contending with these obstacles that impeded his progress, Roebuck became financially embarrassed, from the failure of his undertaking in the Borrowstowness coal and salt works, and was unable to continue with the engine manufacture. In 1773 Roebuck sold his interests to Matthew Boulton, of Birmingham, whose metal works was the most complete in England. This meant much to Watt, especially since a portion of the works was allotted to him in order that he might carry out his ideas on a grand scale. It was at this plant that the engine reached its final form, as shown in Fig. 2.

The thermal efficiency of Newcomen's best engine as obtained from its operating data was about 1.5 per cent. This may be compared with the thermal efficiency of Watt's engine which can be estimated from the fuel consumption, which was one-hundred weight of Wednesbury slack and lump coal, while the engine made 3,000 strokes and at each stroke raised 7.8 cubic feet of water 24 feet high. With these values the thermal efficiency is about 3 per cent., which is

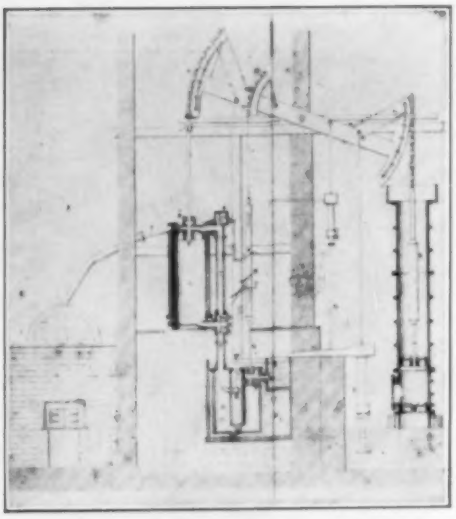


FIG. 2. WATT'S FIRST STEAM PUMPING ENGINE.
FROM "A MANUAL OF THE STEAM ENGINE," BY R. HOBLYN. 1842.

indeed a remarkably high value for this early engine and is by far the highest value for any engine of that time.

In making the changes of plant location and the necessary improvements on the engine much time was required; as a consequence the patent was about to expire and the engine was not yet placed on the market. Watt, therefore, applied for an extension of time on his patent, and in 1775 an act was passed to extend the original patent of fourteen years to twenty-five years from that date; so that in the whole the patent was in force more than thirty years. The granting of this extension in itself speaks well of Watt's work and the merits of his engine. The writers have been unable to find any other record where such an extension has been made on any other patent.

The tremendous commercial success of Watt's engines was not due entirely to his own efforts, but depended largely on the business judgment and experiment of his esteemed partner, Boulton, who wrote to Smeaton in 1778 as follows:

> We are systematizing the business of engine making, as we have done before, in the button manufactury; we are training up workmen and making tools and machines to form the different parts of Mr. Watt's engines, with more accuracy, and at a cheaper rate than can possibly be done by the ordinary methods of working. Our work shop and apparatus will be of sufficient extent to execute all the engines which are likely to be soon wanted in this country; and it will not be worth the expense for any other engineers to erect similar works, for that would be like building a mill to grind a bushel of corn. . . .

The chief, if not the only, sales arguments for the Watt engines were their unusual records for operating economy as compared with the Newcomen engines (already in service) in the use of fuel. For example, he states that "all we ask from those who choose to have our engines is the value of one-third part of the coals which are saved by using our improved machines instead of the old. . . .

In conclusion, it may be said that, before Watt's time, the steam-engine was exclusively a steam pump, very slow working, extremely cumbersome and excessively wasteful of fuel. His first improvements made it quick-acting, powerful and efficient, but still left it a steam pump, entirely replacing the Newcomen engines. James Watt's later developments and inventions adapted the steam-engine to drive machinery of all kinds and left it virtually what it is to-day. Later designs have developed more direct methods of (1) connecting the piston with the crank, (2) higher working pressures and (3) compound expansions; all of which were considered by Watt.

James Watt is also credited with the following developments: condensing steam-engine; double-acting steam-engine; steam cylinder jacketing; expansive working of steam; piston stuffing box; wet air pump (air and condensate pump); circulating pump; indicator; mercury steam gauge; fly-ball governor; throttle valve; stroke counter; steam hammer, and statuary copying machine.

Bachrach

DR. JAMES B. CONANT

DISTINGUISHED FOR HIS WORK IN ORGANIC CHEMISTRY; PRESIDENT OF HARVARD UNIVERSITY.

THE PROGRESS OF SCIENCE

THE HARVARD TERCENTENARY CONFERENCE OF ARTS AND SCIENCES

THE Harvard Tercentenary Conference of Arts and Sciences to be held in Cambridge from August 31 to September 12, the fortnight preceding the three-day celebration on September 16, 17 and 18, will be one of the most distinctive and important features of Harvard's tercentenary year. It was decided more than two years ago that, although the festive and retrospective aspects of such an anniversary were not to be overlooked, the celebration should itself be primarily the occasion for a contribution to learning and a stimulus to scholarly achievement. So, before the concluding ceremonies bring to Cambridge a great concourse of the alumni and friends of Harvard, including some six hundred delegates from about four hundred and eighty universities, colleges, learned societies and other bodies concerned with higher education, about 2,500 American and Canadian scholars will gather to hear the papers and lectures to be given by seventy-three of the most distinguished men chosen from various fields of learning.

JOHN HARVARD
A STATUE BY DANIEL CHESTER FRENCH.

The process by which the contributors to the conference were chosen is itself significant. While the standard set was high, the selection was nothing so difficult or invidious as an attempt to make the final list a would-be official rating of the world's best scholars to the exclusion of others, on the assumption that they did not "rate" inclusion. Some five hundred names received consideration, divided with approximate equality among the "quadrants" of the Physical and Mathematical Sciences, the Biological Sciences, the Social Sciences and the Humanities—or Arts and Letters, to use a preferred designation. The final selection was controlled by two considerations: First came distinction and continued productivity, rather than eminence alone. This test was applied to all. Second came special competence, to contribute to the three collaborative symposia on prearranged subjects thought to possess peculiar timeliness and importance. These criteria are reflected in the program, which shows in the Physical and Mathematical Sciences, and to some extent in the Biological Sciences, a series of contributions embodying what happen to be the special interests of the individual contributor; while the rest of the program reveals an attempt to secure what is called "a common attack" by representatives of the Biological Sciences, the Social Sciences and Arts and Letters, upon problems of man in his relation to his fellows and to nature. If, as it is hoped, the conference plan is itself a contribution to the strategy of man's search into the unknown, the hope is based upon the emphasis placed upon problems to be solved rather than upon one or more conventional disciplines as self-sufficient channels of approach.

Invitations to register as members of the conference were distributed widely among professors in the leading universities and colleges of the United States

Harvard College Library

THE EARLIEST CONTEMPORARY VIEW OF HARVARD COLLEGE, 1726

FROM AN ENGRAVING DRAWN BY WILLIAM BURGIS.

and Canada as well as among research institutes. The limits of space in the largest lecture halls have compelled a limitation of the membership to 2,500. Even with this limitation, overflow arrangements, with loud-speakers, will probably have to be made in adjoining halls, in the case of the collaborative symposia. Admission to lectures will be controlled by badges of different colors, each indicating one of the four "quadrants." Preference in admission will be given to those wearing the color corresponding to the subjects of the sessions. Associate membership will be granted to a limited number of applicants, to whom no assurance can be given that they can hear papers otherwise than by loud-speaker in a neighboring hall. Even at the few lectures designated as "public," the members of the conference will probably fill the lecture halls, thus forcing others to content themselves with the loud-speakers nearby or to resort to the radio—for the lectures likely to be of greater public interest will be broadcast by the Boston, non-profit, educational station W1XAL operating on short-wave frequencies of 6.04 megacycles (49.67 meters) or 11.79 megacycles (25.45 meters).

Nominally extending over the two weeks from August 31 to September 12, the program of the first week has chiefly to do with the Mathematical and Physical Sciences and is coordinated with sessions of the American Mathematical Society, the Mathematical Association of America and the American Astronomical Society. The second week begins with the only plenary session, at which addresses will be made by President James B. Conant and Jerome D. Greene, di-

rector of the tercentenary celebration and chairman of the executive committee of the conference, on September 7.

The conference will be opened with a lecture by Professor Ronald A. Fischer, professor of eugenics in the University of London, on "Uncertain Inference." This will initiate the symposium on the Mathematical and Physical Sciences.

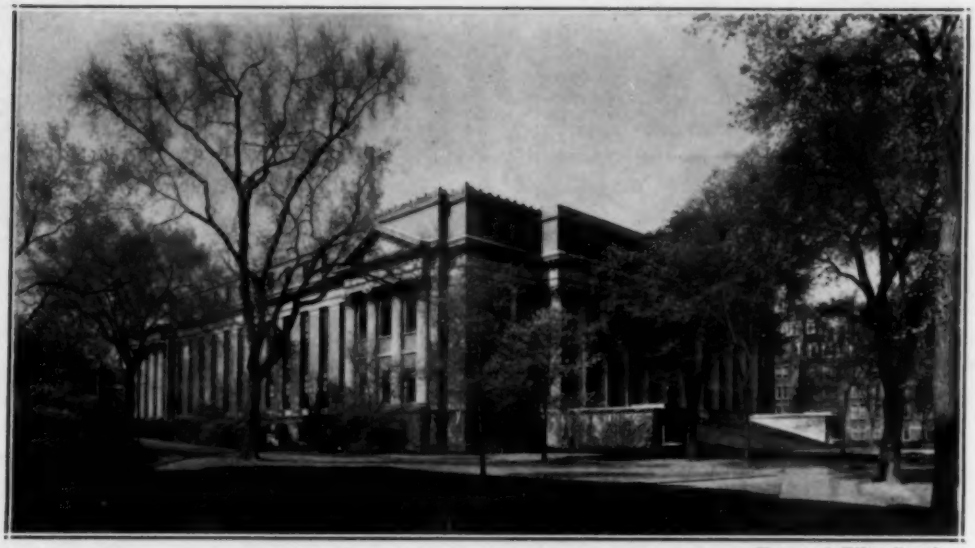
The first collaborative symposium will be devoted to "Factors Determining Human Behavior," which will open on the morning of September 7 with a lecture by Dr. Edgar Douglas Adrian, Foulerton professor of the Royal Society in the field of physiology. An evening lecture, by Dr. Abbott Lawrence Lowell, emeritus president of Harvard University, on "An Example from the Evidence of History," in the afternoon will be followed by a late evening lecture by Dr. Bronislaw Malinowski, on "Culture as a Determinant of Behavior."

The second collaborative symposium, entitled "Authority and the Individual," will occupy two days. It will be divided into four parts, one entitled "The State and Economic Enterprise." Under this section on September 8 Dr. William E. Rappard, professor of public finance in the University of Geneva, will read a paper on "Economic Nationalism." The second section of this symposium is entitled "Stability and Social

Harvard Institute of Geographical Exploration

AERIAL VIEW OF HARVARD UNIVERSITY

SHOWING THE CHARLES RIVER AND BOATHOUSE IN THE FOREGROUND. THE HOUSES WHERE THE UPPER CLASSMEN LIVE FACE THE RIVER. IN THE REAR, UPPER CENTER, ARE THE CHAPEL, LIBRARY AND FRESHMAN DORMITORIES, IN THE HISTORIC COLLEGE YARD. THE COLLEGE WAS FOUNDED IN 1636, AND THE FIRST BUILDINGS WERE IN THE COLLEGE YARD.



Harvard Film Service

WIDENER LIBRARY OF HARVARD UNIVERSITY

CONTAINING 3,800,000 VOLUMES, MAKING IT THE LARGEST UNIVERSITY LIBRARY IN THE WORLD.

Harvard Film Service

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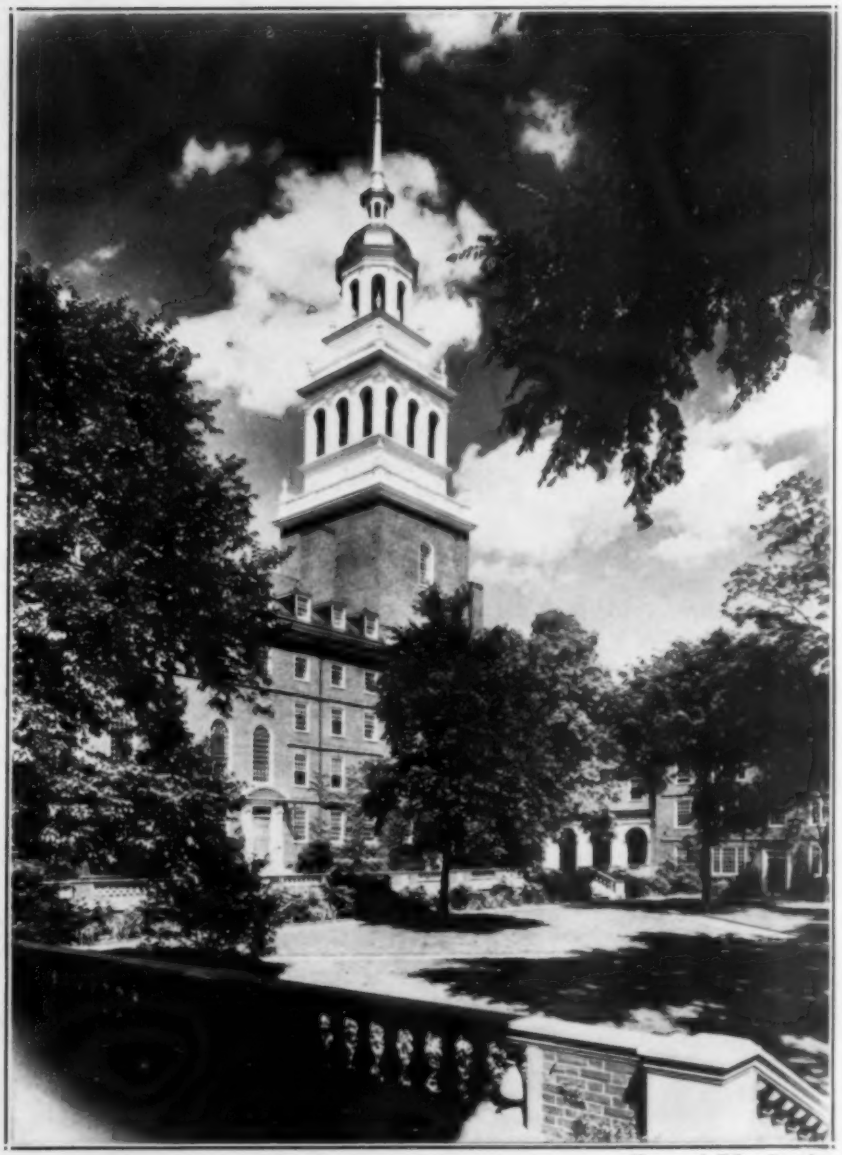
MASSACHUSETTS HALL OF HARVARD UNIVERSITY, WHICH WAS BUILT IN 1720. ONCE IT WAS OCCUPIED BY COLONIAL TROOPS DURING THE REVOLUTIONARY WAR; NOW IT IS USED AS A DORMITORY FOR FRESHMEN.



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ONE OF THE DORMITORIES FOR UPPER CLASSMEN.

Change." The main feature of the latter will be an evening lecture by Dr. John Dewey, professor of philosophy, emeritus, in Columbia University, on "Authority and Resistance to Social Change." The third sub-topic in this symposium is entitled "The Place and Functions of Authority." Taking part in this group of papers will be Corrado Gini, professor of statistics and sociology in the University of Rome. Arts and Letters is represented in the fourth section of this symposium on "Authority and the Individual," under the title "Classicism and Romanticism." An important feature of this part of the program is a lecture by Dr. E. J. Dent, professor of English in the University of Cambridge, on "The Historical Approach to Music." This lecture is, however, to be given on September 3.

The third collaborative symposium will bear the pregnant title, "Independence, Convergence and Borrowing in Institutions, Thought and Art." "Europe and the Near East" and "The Middle Ages" are the two divisions under this head. This symposium will be concluded by an evening lecture, entitled "Medieval Universalism and its Present Value," by Dr. Étienne Gilson, who is professor of philosophy in the Collège de France. To readers of the SCIENTIFIC MONTHLY, possibly the symposia on the natural and exact sciences will be of even greater interest than the program outlined above. It will be divided into three parts, "Europe and the Near East," "The Middle Ages" and "East and West."

This symposium on the "Biological Sciences" will begin on September 8, and contains four divisions: The first is "Various Aspects of Biology" (under which are gathered miscellaneous papers by distinguished foreign and American men working in the biological sciences); "Experimental Morphology"; "Parasitism"; the final section of this symposium on the "Biological Sciences" will be entitled "The Applications of Physical Chemistry to Biology." Among the speakers in this group will be Dr. J. H. Northrop, a member of the Rocke-

STUDENT RESIDENCES ALONG THE CHARLES RIVER

feller Institute, who will address the conference on "The Use of Isotopes as Indicators in Biological Research."

The fifth, the last of these collaborative symposiums, is one on the "Physical Sciences," which will have sections on "Mathematics," "Astrophysics," "Cosmogony," "Cosmic Radiation," "Nuclear Physics" and "Communication Engineering." The latter is by Dr. Frank B. Jewett, of the Bell Telephone Laboratories, whose picture was reproduced in the August issue of the SCIENTIFIC MONTHLY in connection with the award to him of the Franklin Medal of the Franklin Institute.

It is of special interest to note that the sessions on "Nuclear Physics," which are to be held on September 8 and 9, are made up entirely of American physicists.

The session on "Geology and Geophysics" will consist of a lecture by E. B. Bailey, professor of geology in the University of Glasgow, and of contributions from American men of science.

The section of chemistry will have the following papers: by Peter Debye, professor of physics in the University of Leipzig, on "The Structure of Liquids"; by Hans Fischer, professor of chemistry in the Technische Hochschule of Munich, on "Chlorophyll"; by Leopold Ruzicka, professor of chemistry in the Technische Hochschule of Zurich, on "The Male Sex Hormones."

Friedrich Bergius, of the Deutsche Bergin-Aktiengesellschaft in Heidelberg, will present the only paper in connection with the section on "Industrial Chemistry." His contribution is entitled "The Conversion of Wood into Carbohydrates and Technical Problems in the Industrial Use of Concentrated Hydrochloric Acid."

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SUMMER CONFERENCES ON SPECTROSCOPY AND ITS APPLICATIONS, AND ON COLOR, AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

IN the present age of scientific specialization any cooperative effort which overlaps the arbitrary lines of demarcation between the sciences is of unusual interest. An example of this is the series of one-week conferences on spectroscopy held in the George Eastman Laboratories of the Massachusetts Institute of Technology during the past four summers. Biologists, chemists, physicists, astronomers, metallurgists, engineers, agricultural scientists, physicians and representatives of other branches of science and industry have met together in increasing numbers to discuss spectroscopy, particularly as applied to the analysis of materials.

The first conference, arranged in the summer of 1933 by Professor George R. Harrison, director of the research laboratory of experimental physics at the institute, attracted some seventy scientists from America and abroad. As knowledge of the applicability of spectrographic methods of analysis to various fields has grown, interest in the conferences has spread, with a resulting increase in enrolment from year to year, until at the conference just concluded over 200 were in attendance during the first three days, when this subject was under discussion. An additional 200 persons registered at a conference on color held during the last three days of the week beginning on July 20. The program of the spectroscopy conference was in charge of Professor Harrison, while that of the color conference was under the chairmanship of Professor Arthur C. Hardy, of the physics department of the institute, president of the Optical Society of America.

SECTION OF THE TRACK FOR PLATE-HOLDERS

IN THE LARGE SPECTROSCOPIC ROOM OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY'S NEW SPECTROSCOPIC LABORATORY. THE DIAMETER OF THIS CIRCULAR TRACK IS TEN METERS.

MACHINE FOR MEASURING AND COMPUTING WAVE-LENGTHS

OF SPECTRUM LINES 20 TIMES FASTER THAN HAS HITHERTO BEEN POSSIBLE HAS BEEN DEVELOPED IN THE DEPARTMENT OF PHYSICS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY BY PROFESSOR GEORGE R. HARRISON, DIRECTOR OF THE INSTITUTE'S SPECTROSCOPY LABORATORY.

Although a wide variety of subjects was covered at the spectroscopy conference, the meetings were noteworthy for the willingness of specialists in a given field to listen to papers presented by workers in other fields. Arguments between biologists on such things as the absorption spectra of haemoglobin derivatives were participated in wholeheartedly by physicists, chemists and others not particularly familiar with biological terms but having very definite ideas as to proper spectrographic procedure, with the result that numerous lively discussions featured the meetings.

On Monday morning a series of five half-hour papers on analysis of materials by means of the emission spectrum was given by W. F. Meggers, of the National Bureau of Standards; G. O. Langstroth, of McGill University; David Richardson, of the Massachusetts Institute of Technology; O. S. Duffendack, of the University of Michigan; and Mary E. Warga, of the University of Pittsburgh.

The Monday afternoon session was devoted to biological spectroscopy, with papers by G. I. Lavin, of the Rockefeller Institute; L. H. Flint, of the U. S. Department of Agriculture; J. S. Foster, of McGill University; and E. S. Miller, of the University of Minnesota.

Tuesday morning was devoted to metallurgical spectroscopy, papers being given by J. S. Owens, of the Dow Chemical Company; D. J. Crawford, of the Watertown Arsenal; R. A. Sawyer, of the University of Michigan; H. B. Vincent, of the same institution; and L. Strock, of Lucius Pitkin, Inc.

Biological spectroscopy was again taken up on Tuesday afternoon, papers being given by D. L. Drabkin, of the University of Pennsylvania; D. R. McRae, of McGill University; T. R. Hogness, of the University of Chicago; C. B. Coulter, of Columbia University; and L. E. Gaul, of New York City.

Absorption spectrophotometry was the subject of Wednesday morning's discussion, with papers by Professor Hogness; Brian O'Brien, of the University of Rochester; Egon Lorenz, of the U. S. Public Health Service; Dr. Drabkin; and O. R. Wulf, of the U. S. Bureau of Chemistry and Soils.

General spectroscopy was discussed on Wednesday afternoon, three papers being read, by Dr. Meggers; H. A. Robinson, of the University of Uppsala; and Dr. O'Brien. A two-hour general discussion of spectrographic methods concluded the spectroscopy conference.

Equal interest was shown in the color conference, papers being given by L. A. Jones, of the Eastman Kodak Company; John W. Forrest, of the Bausch and Lomb Optical Company; H. E. Ives, of the Bell Telephone Laboratories; K. S. Gibson, of the National Bureau of Standards; J. L. Michaelson, of the General Electric Company; G. F. A. Stutz, of the New Jersey Zinc Company; C. E. Foss, of the International Printing Ink Corporation; Lester C. Lewis, of the Mead Corporation; Selig Hecht, of Columbia University; Deane B. Judd, of the National Bureau of Standards; D. L. MacAdam, of the Eastman Kodak Company; F. W. Sears, of the Massachusetts Institute of Technology; H. P. Gage, of the Corning Glass Works; Walter M. Scott, of Gustavus J. Esselen, Inc.; Dorothy Nickerson, of the U. S. Bureau of Agricultural Economics; F. H. Norton, of the Massachusetts Institute of Technology; K. S. Gibson, of the National Bureau of Standards; A. W. Kenney, of E. I. du Pont de Nemours and Company; M. Rea Paul, of National Lead Company; W. D. Appel, of the National Bureau of Standards; I. H. Godlove and R. E. Rose, of the du Pont Company.

Registration at both conferences was free and open to any one interested in the subjects under discussion. A similar conference or group of conferences is being planned for next summer.

UTILIZATION OF THE WHOLE COTTON PLANT

At the second Dearborn conference of the Farm Chemurgic Council, Dr. Frank K. Cameron, of the University of North Carolina, read a paper describing the work of his students on "Whole Cotton as a Source of Oil and Alpha Cellulose."

CUTTING COTTON WITH A MOWING MACHINE

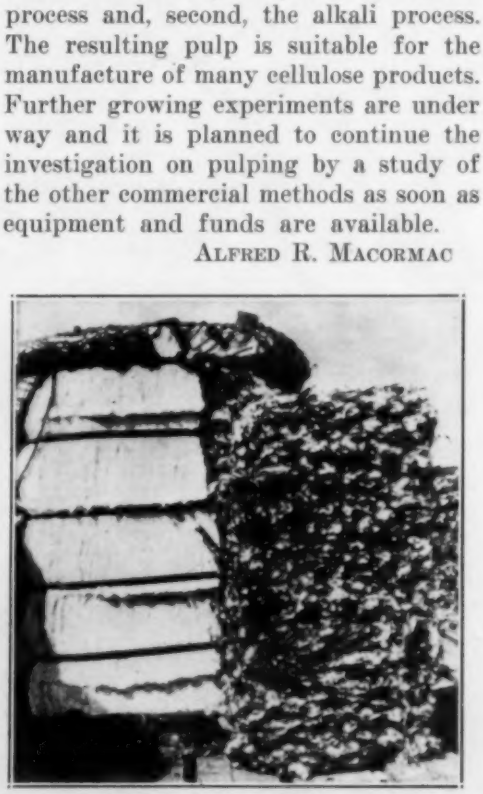
BALING THE WHOLE COTTON PLANT

Several years ago, when the over-supply of lint cotton became a matter of concern, the investigators became interested in the possibilities of growing cotton as a source of cellulose. If the cotton plant could be developed into such a source it would be of considerable benefit to the southeastern states, which are at a disadvantage in competition with the southwestern states in the growing of lint cotton. The prospect of a new outlet for the chief money crop of this region, without radical changes in the present farm practice, was a primary incentive to the series of investigations carried on since 1929.

The growing experiments have been made by N. W. Dockery near Rockingham, N. C. Crowding and starving the plant forced it to mature early and give a larger proportion of lint cotton than does the normal plant. The crowding also caused the great majority of the bolls to ripen at the same time. The plants reach a maximum cellulose content of about 50 per cent. about 25 weeks after planting. The plants are cut with a mowing machine and immediately baled in the field. This baled material may be stored without deterioration. Some bales have stood in the open without injury for five years. It has been found essential that the material be stored under conditions which will prevent the accumulation of inorganic dust.

The baled material is comminuted to a uniformly ground mass of fluffy nature (because of the large proportion of lint cotton). An ordinary agricultural type of hammer mill serves the purpose admirably. Thus a material is obtained which is in a much more favorable condition for pulping than the usual wood chips. The oil is extracted by solvents and an oil similar to cottonseed oil and a wax similar to beeswax recovered. The residue has, to date, been made into a pulp by two methods. The two processes studied are, first, the nitric acid process and, second, the alkali process. The resulting pulp is suitable for the manufacture of many cellulose products. Further growing experiments are under way and it is planned to continue the investigation on pulping by a study of the other commercial methods as soon as equipment and funds are available.

ALFRED R. MACORMAC



125-POUND BALE OF WHOLE COTTON PLANT COMPARED WITH 500-POUND BALE OF LINT COTTON

THE ROLE OF TIME IN THE LEARNING PROCESS

THE writer has recently succeeded in isolating a process of mental growth which may require a complete reordering of the present-day conceptions of human learning.[1] In essence, the findings rest upon the use of an experimental device which reduces the adult subject to a beginning point only slightly above that of a child. From this low point the growth called learning is charted on its upward rise and is found to present two distinct, even opposed processes. The earlier or primary growth seems to require a new frame of thought and a new logic, while the later, secondary process is in complete accord with our present conceptions.

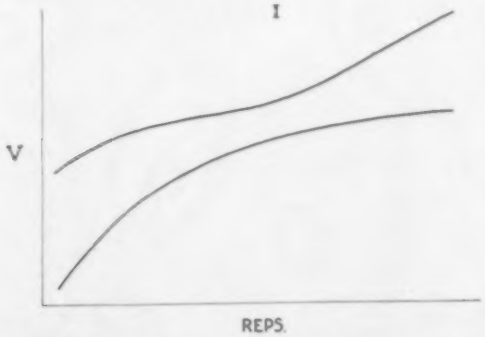
The experimental technique employed in these studies involves a mirror-vision coordination where the subject traces the outline of a path by means of a mental stylus as the path is revealed by mirror-vision only. The scores begin at a point very close to zero, and the experimental controls at every stage of the learning are very satisfactory.

An indication of the opposed character of the two growth processes is seen in the following: Primary growth is early, secondary is late; individual differences are decreasing in primary growth and increasing in secondary growth; primary growth is a positive function of the length of time interpolated between stimulations; secondary growth rests upon stimulation alone; primary growth is permanent, since time only enhances it, while secondary growth is temporary and requires constant stimulation. Fig. 1, showing the growth processes for a high and low efficiency group, presents the general character of the two growths. As time is interpolated the removal of individual differences at the left is greatly increased. As time is withdrawn, *i.e.*, stimulation increased, the point of greatest constriction moves to the left and falls to a lower point on the graph.

An indication of the havoc wrought in learning theory by the discovery of the primary growth process can be seen in its bearing upon the conception that learning is a selection of random movements. Keep in mind that the reduction of individual differences through this growth is supported by a correlation of $.97 \pm .002$ in a study of 400 adult subjects. The poorer the subject the more he gains, which means that those with many good movements do not gain in proportion to the number of good movements, random or otherwise, since the greater gain is always on the side of the excess of poor movements. The growth rate in the primary process resembles the reduction of volume in a gas brought about by adding weights to the piston: the more disperse the gas, the greater the change.

An indication of the effect of interpolated time on early growth is shown in Fig. 2. The group with the time intervals, though initially inferior, rises to a level far above that of the continuous-practice subjects. The reliability ranges from statistical certainty at the second

[1] Geo. S. Snoddy, "Evidence for Two Opposed Processes in Mental Growth," The Science Press Printing Company, Lancaster, Pa., 1935.



A DIAGRAMMATIC PRESENTATION OF THE EFFICIENCY SCORES (V) OF A VERY SUPERIOR AND AN INFERIOR GROUP PLOTTED AGAINST THE NUMBER OF REPETITIONS.

EARLY EFFICIENCY SCORES (V) OF TWO GROUPS UNDER DIFFERENT CONDITIONS OF PRACTICE. IN GROUP A REPETITIONS WERE SEPARATED BY 24-HOUR TIME INTERVALS AND IN GROUP B PRACTICE WAS CONTINUOUS. LATE IN THE LEARNING THESE TWO GROUPS ARE REVERSED, THE CONTINUOUS PRACTICE BEING SUPERIOR.

repetition to four times this value at the twelfth repetition. Also the continuous-practice group becomes very much more variable as practice continues than is the case with the time-interval group; the stimulation is depressing the poorer members in the group with continuous practice and is increasing their variability. These subjects give every evidence of undergoing punishment. In the time-interval group the situation is reversed: the whole group is not only improving at a higher rate, but the lower subjects are profiting greatly from the time, and individual differences are being reduced. This seems to point unmistakably to the fact that primary growth is stabilization, not selection. A process of contraction is taking place in the individual subject, which is analogous to what takes place in the group or to what occurs in a sand pile when it settles. The survival-of-the-fittest origin of the selection theory gives us no reason to suppose it could explain what actually occurs in learning.

Other experimental devices show the same sequence of opposed growth processes when we are able to get the lowest level of growth under observation. The pursuit rotor has just given one of our research students exactly the same findings as I have indicated above. There is no reason to suspect that the peculiar character of our findings depends upon any other factor than the measuring of a level of mental growth which comes earlier than any we have studied heretofore.

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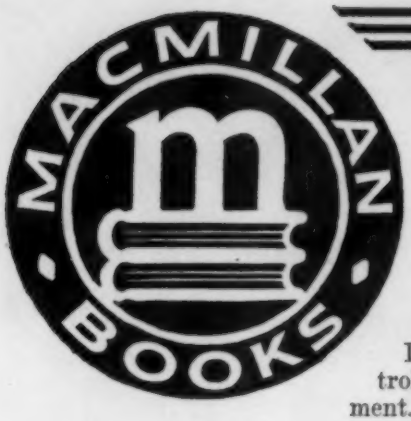

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